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F-86E THRUST AUGMENTATION EVALUATION

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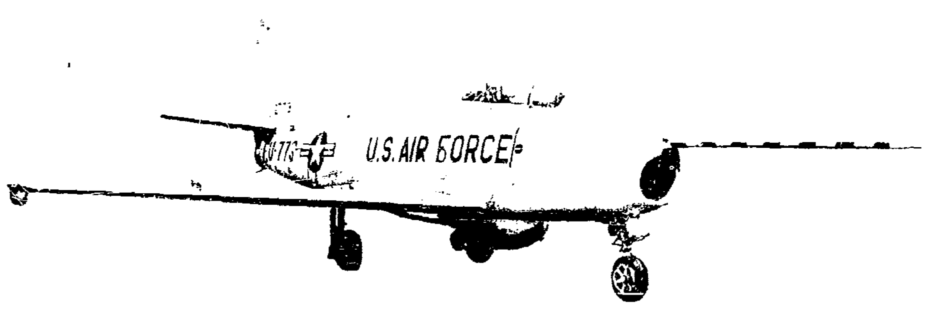

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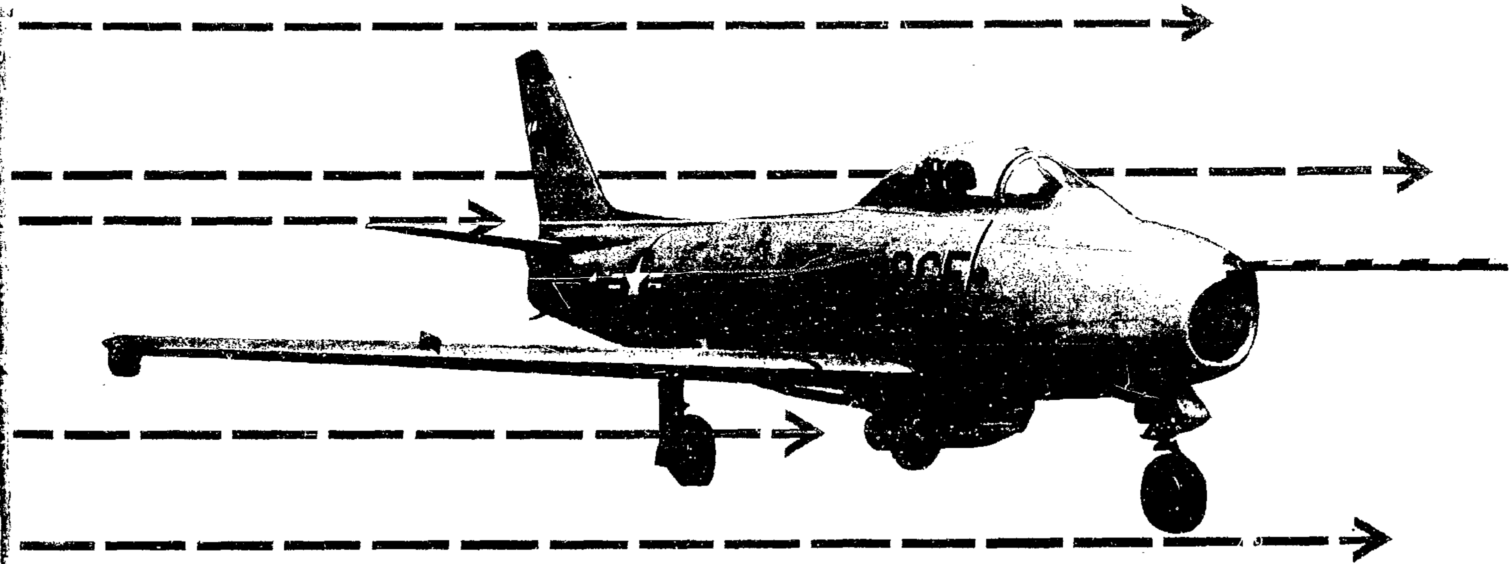

AUGMENTATION EVALUATION

AFFTC-TR-57-1 March 1957

ASTIA Document No. AD-118703

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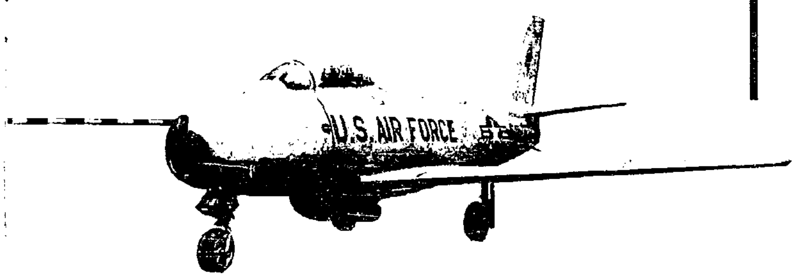

ABSTRACT

The addition of the YLR63-AJ-3 thrust augmentation system to the F-86E aircraft produces high performance for a short duration. Within a limited radius, point-intercept missions are possible at a speed and altitude which are beyond the capability of the standard F-86E aircraft.

With the rocket system ready, but not operating, performance is reduced in all categories because of increased weight and drag. Predominant losses are in time to climb and both total and specific range.

Maintenance and support of the augmentation system is high, but not necessarily prohibitive.

Installations in future aircraft should be buried in the fuselage to reduce drag and pitching moments. The rocket duration should be increased to at least 2 minutes and the thrust should be variable to permit optimum use of the augmented performance.

This report has been reviewed and approved

13 March 1957

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J. S. Holtoner

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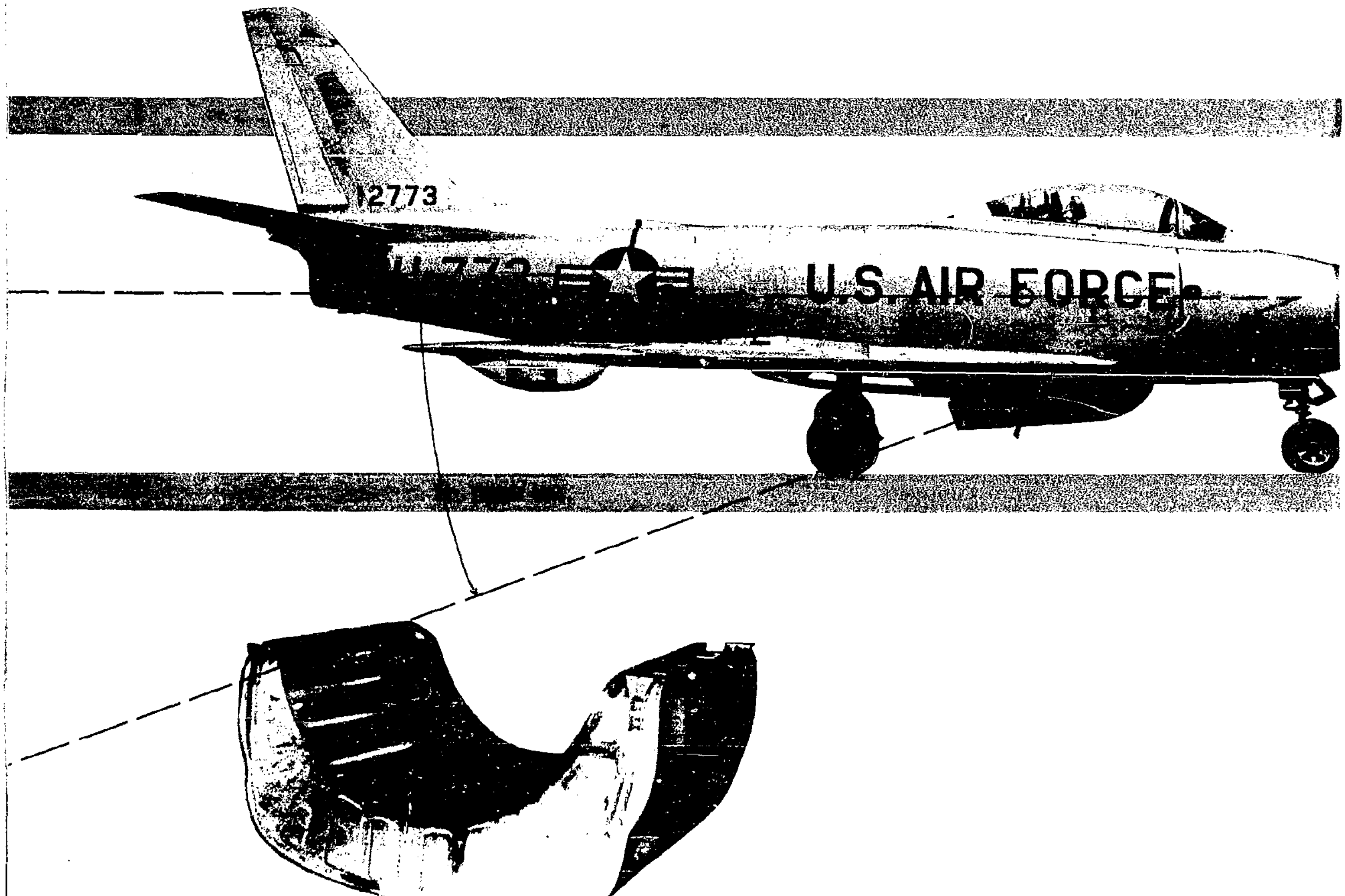
*NOTE: Due to the limited requirement for the information contained in this Appendix, it has been published in a separate volume. Copies of this Appendix can be obtained by writing to the Armed Services Technical Information Agency (see inside cover).



NITRIC ACID TANK

INTRODUCTION

This report presents the results of performance flight tests of the F-86E airplane S/N 51-2773, equipped with a YLR63-AJ-3 rocket engine for thrust augmentation at altitude.

The flight tests were performed at Palmdale, California, during the period 3 October 1956 to 9 November 1956. All instrumentation, aircraft, and rocket engine support was provided by North American Aviation, Incorporated, and the Aerojet-General Corporation. The program consisted of 26 flights, totaling 16:45 hours. Two of these flights were made by Major E. P. Sonnenberg of the Air Proving Ground Command for qualitative evaluation of intercept capabilities.

The aircraft used for these tests differs from a standard F-86E in the following respects:

1. A YLR63-AJ-3 rocket engine is installed under the wing center section in a faired pod. The thrust line of the rocket engine is canted 20 degrees downward from the main engine thrust line.

2. The normal F-86E wing has been modified by the addition of a 6 by 3 inch (F-86F) leading edge, thus removing the slats but increasing the wing area from 287.9 to 302.26 square feet.

3. The main engine inlet screens are not retractable.

4. The aft fuselage fuel cell has been replaced with an aluminum oxidizer tank, reducing the internal fuel capacity from 435 to 330 gallons.

5. The basic weight of the aircraft has been increased from 11,650 to 12,442 pounds. The weight at engine start (no external stores) has increased from 14,716 to 15,987 pounds.

The augmentation rocket is a YLR63-AJ-3, built by the Aerojet-General Corporation. The fuel is standard JP-4 from the normal aircraft fuel cells. The oxidizer is white fuming nitric acid (WFNA) supplied through an external line from an internal 85 gallon aluminum tank. The rocket is capable of approximately 70 seconds total running time (limited by oxidizer supply), and may be shut down and re-started as many as six times during a flight. Approximately 3.5 seconds are required for initial lighting, with approximately 0.2 seconds for subsequent shut-offs and 2.5 seconds for re-starts. The rated thrust of the rocket engine increases with altitude from approximately 3600 pounds at sea level to over 4000 pounds at 60,000 feet. Because of the location of the rocket engine, blast, heat, and corrosive effects prohibit ground operation without special provisions which include a water-cooled exhaust tunnel.

TEST RESULTS

climb performance

Military Power Climb Performance: The military power (unaugmented) climb performance is reduced approximately 50 percent by the additional weight (1200 pounds) and additional drag of the rocket installation and fluids. (The reduction is partially due to a lower thrust engine and the presence of fixed screens in the augmented aircraft.)

The performance parameters for military power climbs are presented in Figure 1 of Appendix II and are compared with those of a standard F-86E (Reference 1, Figure 1) in the following table.

COMPARISON OF MILITARY POWER CLIMB PERFORMANCE

No External Stores — Standard Day Conditions

(Rocket Oxidizer and Extras Aboard Augmented Aircraft)

		20,000 Feet			40,000 Feet		
	Take-Off Weight	Time* min.	Distance n. m.	Fuel Used* lbs.	Time* min.	Distance n. m.	Fuel Used* lbs.
Augmented Aircraft	15,669	4.5	30	400	15.8	111	910
Standard Aircraft	14,470	3	22	280	10.5	79	645

*Does not include requirement for start, taxi, take-off, and acceleration to climb schedule.

Augmented Climb Performance: Augmented climbs made from two altitudes (20,000 feet and 41,000 feet) show that the rocket considerably improves climb performance. A rapid increase in altitude of approximately 14,000 feet is available from any altitude during the 70 seconds of rocket burning. At burn-out, the high climb speed can be used for either a zoom to higher altitude or transition to high speed level flight: Augmentation can be used to reduce time to climb at altitudes below 40,000 feet, or to increase the combat ceiling. If augmentation is used from 20,000 feet to 36,000 feet followed by a zoom to 45,000 feet, the total time to 45,000 feet is reduced from 15.5 minutes (for a standard F-86E) to 6.4 minutes. Use of the rocket at the military power combat ceiling of the augmented aircraft (41,000 feet) increases the effective combat ceiling to 55,000 feet at rocket burn-out as compared to 46,000 feet for the standard F-86E. A maximum altitude of approximately 59,000 feet can be reached by a zoom after rocket burn-out. If the rocket is fired at 41,000 feet, a climb to 50,000 feet can be made in about 40 seconds, leaving approximately 30 seconds of augmented high speed flight. After rocket burn-out, about 580 pounds of fuel remain for return to base.

The performance with augmentation from 20,000 feet and from 41,000 feet is shown in Figure 2, Appendix II, and is compared to the military climb performance of the augmented aircraft in Figure 3. Two climb performance summary tables are shown. The first presents the climb performance of the augmented aircraft. The second table shows the increase in climb performance provided by augmentation over that of a standard F-86E.

CLIMB PERFORMANCE

No Eternal Stores — Inlet Screens in Place —
Take-Off Weight 15,669 Pounds —
Standard Day Conditions

	Altitude ft.	R/C ft/min.	T/C* min.	Fuel Used* lbs.	Calibrated Airspeed kts.	Distance* n. m.
MILITARY POWER	Sea level	5,500	0.	0	388	0
	10,000	4,300	1.8	200	360	13.4
	20,000	3,400	4.5	400	322	20
	30,000	2,100	8.1	600	275	56.5
	41,000	500	17.5	960	215	127.1
AUGMENTED FROM 20,000 FEET (Rocket burn-out at 36,000 feet; 1115 pounds fuel remaining)	20,000	14,700	0		375	0
	30,000	14,400	0.67		305	5.5
	36,000	13,850	1.16		265	9.2
	45,000	Zoom	1.9		114	Zoom
AUGMENTED FROM COMBAT CEILING (Rocket burn-out at 55,000 feet; 580 pounds fuel remaining)	41,000	13,180	0		235	0
	50,000	11,450	0.67		195	5.16
	55,000	10,000	1.20		170	9.2
	59,000	Zoom	1.83		130	Zoom

*Does not include requirement for start, taxi, take-off, acceleration to climb schedule, and climb to starting altitude.

COMPARISON OF CLIMB PERFORMANCE UTILIZING AUGMENTATION

No External Stores —
Standard Day Conditions

	Altitude 20,000 ft. Time min.*	Altitude 30,000 ft. Time min.*	Altitude 40,000 ft. Time min.*	Altitude 45,000 ft. Time min.*	Altitude 55,000 ft. Time min.*
Standard aircraft	3	5.6	10.5	15.5	—
Augmented aircraft — Rocket on at 20,000 feet	4.5	5.17	5.9**	6.4**	—
Augmented aircraft — Rocket on at 41,000 feet	4.5	8.08	15.8	17.8	18.7***

*Time does not include allowance for take-off and acceleration.

**Rocket off at 36,000, zoom to approximately 200 knots CAS at 40,000 feet; 112 knots CAS at 45,000 feet.

***Rocket off at 55,000 feet, zoom to approximately 59,000 feet before stall.

■ level flight

Level Accelerations: Level accelerations were made with military power and with military power plus augmentation at 20,000, 30,000 and 40,000 feet. The potential rates of climb determined from these accelerations are plotted versus Mach number, in Figure 4, Appendix II. The peak rates of climb are also plotted on Figures 1 and 2, Appendix II as applicable. Both the rates of climb and the optimum climb schedules checked with climb results for standard day conditions.

The values of level acceleration with augmentation are more than three times those with military power alone. The maximum level flight speeds are increased more than a tenth of a Mach number with sonic speeds possible at 40,000 feet and above. These performance increases are shown in Figure 5, Appendix II, in a plot of rate of change of true airspeed versus Mach number for both military and augmented power at 20,000, 30,000 and 40,000 feet.

RATES OF CHANGE OF TRUE AIRSPEED IN LEVEL FLIGHT

No External Stores —
Inlet Screen in Place —
14,450 Pounds
Standard Day Conditions

		Mach No.	dv/dt kt/sec	Mach No.	dv/dt kt/sec	Mach No.	dv/dt kt/sec	Mach No.	dv/dt kt/sec
20,000 FEET	Military Power	.6	1.35	.7	1.47	.8	0.7	.9	—
	Augmented	.6	5.4	.7	5.9	.8	5.55	.9	3.75
30,000 FEET	Military Power	.6	0.9	.7	0.97	.8	0.68	.9	—
	Augmented	.6	5.1	.7	5.8	.8	5.65	.9	4.2
40,000 FEET	Military Power	.6	0.25	.7	0.4	.8	0.3	.9	—
	Augmented	.6	4.75	.7	5.62	.8	5.6	.9	4.67

■ *Dash:* Dash capabilities from low cruise conditions (approximately 0.65 Mach number) are markedly improved. With augmentation, the aircraft reaches maximum level flight speed within approximately 45 seconds. Without augmentation, several minutes are required to attain a lower maximum speed. With augmentation at 40,000 feet, the true airspeed increases from 370 knots to 575 knots in 50 seconds, an increase of 205 knots. During this same period under military power, the speed increases 17 knots to 387 knots. The standard day dash capabilities at 20,000 30,000 and 40,000 feet are presented as time histories of dv/dt, true airspeed, and calibrated airspeed in Figures 6, 7 and 8 of Appendix II. As shown in the previous table, acceleration occurs near 0.7 Mach number.

LEVEL ACCELERATION CAPABILITIES

No External Stores
Inlet Screens in Place
14,450 Pounds
Standard Day Conditions

		Time sec.	V_c kts.	V_t kts.	Time sec.	V_c kts.	V_t kts.	Time sec.	V_c kts.	V_t kts.	Time sec.	V_c kts.	V_t kts.
20,000 FEET	Military power	0	292	390	15	312	413	30	328	436	45	345	455
	Augmented	0	292	390	15	362	477	30	421	551	45	443	580
30,000 FEET	Military power	0	234	370	15	245	385	30	254	400	50	267	420
	Augmented	0	234	370	15	292	455	30	347	533	50	375	570
40,000 FEET	Military power	0	190.5	370	15	193	375	30	197	380	50	201	387
	Augmented	0	190.5	370	15	237	453	30	284	530	50	313	575

The maximum level flight true airspeeds with military power are reduced by the increases in drag associated with the rocket pod. However, the maximum speeds with augmentation are as much as 59 knots faster (at 40,000 feet) than those of the standard airplane. The maximum speeds are compared in the following table at 20,000, 30,000 and 40,000 feet for standard day conditions.

COMPARISON OF MAXIMUM LEVEL FLIGHT TRUE AIRSPEEDS

Standard Day Conditions

Aircraft	Power	20,000 ft.	30,000 ft.	40,000 ft.
Augmented	Military	—	515*	500*
Augmented	Augmented	580	570	575
Standard	Military	552	529	516

*Indicate estimated values.

■ *Unaugmented Level Flight:* The addition of the rocket as an external installation and the inclusion of approximately 1140 pounds of rocket fluids, carried until the rocket is used, combine to considerably reduce the speed and range performance of the modified aircraft. The total range is further reduced by the replacement of 105 gallons of internal fuel with oxidizer. These effects are less pronounced at higher speeds where the relative drag of the pod is less and the induced drag increases due to increased weight are reduced. The presence of inlet screens on the augmented aircraft reduces performance slightly at all speeds.

Level flight performance curves are presented in Appendix II, Figures 12, 13, 14 and 15, for standard conditions. In Figure 12, rpm versus calibrated airspeed are presented for the modified aircraft at 20,000 and 35,000 feet and for a standard aircraft (Reference 1, Figure 9) at 35,000 feet. Corrected rpm ($N/\sqrt{\theta_a}$) versus Mach number are plotted in Figure 13. Nautical air miles per pound of fuel versus true airspeed are compared for the augmented and the standard aircraft in Figure 14. Nautical air miles per pound of fuel versus Mach number for the augmented aircraft are presented in Figure 15. No fuel flows were obtained at 20,000 feet, since the test at this altitude consisted of a series of short airspeed calibration points A summary of the test results for the standard and augmented aircraft at 35,000 feet is tabulated for comparison of the two aircraft on page 6.

COMPARISON OF LEVEL FLIGHT PERFORMANCE

No External Stores — Main Engine Power — 35,000 feet — Standard Day Conditions — Standard Aircraft 13,000 Pounds — Augmented Aircraft 14,400 Pounds

RPM	6560*		6900**		7300		7700		7950	
Aircraft	Aug.	Std.	Aug.	Std.	Aug.	Std.	Aug.	Std.	Aug.	Std.
Calibrated Airspeed — kts.	Stall	253	236	286	280	300	296	306	302	309
True Airspeed — kts.	—	432	406	482	473	503	497	513	506	517
NAMPP	—	.332	.286	.299	.253	.261	.211	.237	.18	.228

*RPM for maximum range, standard aircraft.

**RPM for maximum range, modified aircraft.

The reduction in level flight performance with the rocket ready but not operating is especially evident in this table. Under maximum range conditions at 35,000 feet, the true airspeed has been reduced 6 percent and the specific range 13.8 percent.

stability and control

Moderate control problems are created at rocket light and rocket burn-out due to the pitching tendencies developed by the rocket. These tendencies become more severe with increased altitude and/or reduced airspeed. The two program test pilots felt that the pitch-up at rocket-start can temporarily upset a smooth flight path but both were making smooth transitions after a limited number of firing flights. The Air Proving Ground Command pilot felt that the pitch-down at rocket-off was more pronounced but he encountered no difficulties in returning to smooth flight at military power. At no time in any of the flights did required elevator deflection approach the limits of elevator travel. Time histories of elevator deflection from trim during periods immediately after rocket light and rocket burn-out are presented for altitudes of 20,000, 30,000 and 40,000 feet in Figure 9 of Appendix II. The plotted curves show an apparent increase in oscillatory motion (or ease of over correction) with altitude. The maximum deflections required are summarized in the following table.

ELEVATOR DEFLECTIONS FROM TRIM TO COUNTER PITCHING TENDENCIES WITH ROCKET OPERATION

Test Conditions

ROCKET STARTING			
Altitude — ft	20,000	30,000	40,000
Maximum Deflection — deg.	3.1 L.E. Up	3.8 L.E. Up	6.6 L.E. Up
ROCKET BURN-OUT			
Altitude — ft.	20,000	30,000	40,000
Maximum Deflection — deg.	1.0 L.E. Down	3.4 L.E. Down	6.2 L.E. Down

The stick forces required were not excessive but were abrupt and resulted in over-control in the initial firings made without lead trim. A technique of hitting trim during the rocket starting delay produced smooth entries to augmented flight.

maneuvering flight

There is a definite increase in maneuvering performance when the augmentation system is used. The load factor available is higher at similar speeds and the useable speed range for turns is increased when compared to a standard F-86E. In addition, the airspeed loss during accelerated maneuvers is much less.

Although no wind-up turns were made during the Phase IV tests on the standard F-86E, the same aircraft was used for pace and chase during this program. In all augmented maneuvering tests the superiority of the augmented aircraft was evident. Each wind-up turn was started with the standard aircraft in an optimum firing position. All turns were completed with the augmented aircraft gaining position at a higher airspeed.

As would be expected with an increase in weight and drag (and approximately 5 percent reduction in thrust), the modified aircraft is out-performed at military power.

The relative performance is presented in Figure 10, Apendix II, as load factor available at the stall versus Mach number for standard weights and altitudes. The darkened symbols (uncorrected data) showing the performance of the standard aircraft indicate the gains in performance with augmentation and the losses at military power. Since the two program test pilots consistently differed in interpretation of the stall boundaries and since the aircraft can definitely fly on the higher boundaries, the apparent coefficient of lift curves are faired on the higher coefficients of lift.

The maneuvering capabilities of the modified aircraft are increased roughly 50 percent by utilizing augmentation. At 0.8 Mach number the rate of turn is increased from 6.7 to 10.2 degrees per second at 30,000 feet and from 3.8 to 6.3 degrees per second at 40,000 feet. For these same conditions, the radii of turn decrease from 1.15 to 0.75 nautical miles at 30,000 feet, and from 1.85 to 1.15 miles at 40,000 feet. These figures are for standard conditions during wind-up turns at the load factors shown in Figure 10. The maneuvering capabilities throughout the Mach range tested are presented in Figure 11, Appendix II, for altitudes of 30,000 and 40,000 feet. A summary of Figures 10 and 11 is presented in the following table.

MANEUVERING CAPABILITIES

No. External Stores
Inlet Screens In Place
Standard Day Conditions

	Mach Number	Load Factor — g		Rate of Turn — deg/sec		Radius of Turn — n.m.	
		Military	Augmented	Military	Augmented	Military	Augmented
30,000 Feet — 14,750 Pounds	0.65	2.6	3.45	6.9	9.6	0.85	0.6
	0.75	3.03	4.35	7.1	10.2	1.0	0.68
	0.85	2.95	4.45	6.0	9.6	1.3	0.83
	0.90	—	4.2	—	8.4	—	1.0
40,000 Feet — 14,580 Pounds	0.6	1.5	1.9	3.5	5.2	1.6	1.05
	0.7	1.85	2.5	4.1	6.1	1.55	1.05
	0.8	1.95	2.85	3.8	6.3	1.85	1.15
	0.9	—	2.7	—	5.4	—	1.55

The superior maneuvering capabilities of the modified aircraft (which had the higher wing loading) can be attributed to a combination of the improvements with a 6 by 3 solid leading edge and the upward thrust component of the canted rocket. The pilot's interpretation of the stall boundary also might be influenced by the "solid" feeling of less loss of airspeed with augmentation.

airspeed calibration

The position error corrections for the nose boom installation are presented in Figures 21, 22 and 23 of Appendix II. A theoretical extrapolation was made (Reference 2) to the Mach numbers expected to be reached during the tests. The normal pitot-static system was not connected.

These calibrations were used for correcting maneuvering flight data although the additional errors caused by increased angle of attack are not known. The resulting slight errors in Mach numbers lead to the use of the term "apparent coefficient of lift" during accelerated maneuvers (Figure 10).

the main engine

The main engine used during these tests was slightly low in thrust and high in fuel flow when compared to the engines used in earlier tests on a standard aircraft (Reference 1, Figures 23, 24, 26). Some (but not all) of this reduction in performance is caused by the presence of inlet screens. The remainder could be caused by any or all of the following modifications to the main engine fuel system.

1. The normal booster pumps in the center wing fuel cell have been replaced by two-speed Thompson type B-25 pumps. At rocket arming, these two pumps switch from normal to emergency output to supply the rocket as well as the main engine with fuel. The fuel supply at "NORMAL" should be adequate for the main engine.

2. The main engine driven fuel pump has been changed to a derated pump with a capacity of about 7500 pounds per hour. This change was necessary to reduce engine over-speed and over-temperature problems at altitudes above 50,000 feet (over-temperature still occurred). The reduced fuel flows available reduce the engine acceleration characteristics by about 50 percent and reduce maximum rpm from 100 percent at low altitudes and high Mach numbers (this condition was never encountered). The fuel pressure to the fuel regulator is affected.

3. The VS-2 fuel regulator oil supply and return lines are capped to isolate the regulator from the main oil tank (where boiling could occur).

The effects of operating on a limited internal oil supply are unknown. No internal modifications were made to the main engine.

The results of calibration tests on the main engine are presented in Figures 16 through 19 of Appendix II with the thrust of the earlier Phase IV engine included in Figure 16.

Several flame-outs occurred during the program, always shortly after rocket shut-down and usually during zooms at reduced load factor following rocket climbs. In each case, normal airstarts were obtained.

the rocket engine, functional analysis

Operations:

The YLR63-AJ-3 is a 3587 pound nominal sea level thrust, pump fed, liquid rocket engine capable of six repeated starts in a single flight. Firing duration of the rocket is rated at 108 seconds, but the F-86E installation configuration provides oxidizer for only 70 seconds firing time. The rocket will operate at altitudes from sea level to 80,000 feet. The thrust increases with altitude to over 4,000 pounds at 40,000 feet.

The propellents utilized by the YLR63-AJ-3 rocket are white fuming nitric acid (WFNA) as an oxidizing agent and JP-4 fuel or gasoline. The propellents are fed to the thrust chamber by a two-sided pump driven by a common central turbine. Power for driving the turbine-pump unit is derived from a self-contained gas generator. The gas generator utilizes a hypergolic propellent combination, white fuming acid (WFNA) and unsymmetric dimethylhydrazine (UDMH), in the primary combustion chamber and a diluent consisting of a water-methyl alcohol mixture to cool the gas in the secondary chamber. These propellents are contained in positive displacement tanks mounted on the rocket assembly. WFNA and UDMH used in the thrust chamber starter are also drawn from these tanks. The propellents are pressure fed by air to the gas generator and starter. Air for pressurizing these tanks, for control valve actuation, and for purging the starter and gas generator is stored in a non-frangible plastic air bottle mounted on the rocket assembly.

The YLR63-AJ-3 rocket is mounted externally beneath the fuselage of the F-86E aircraft and is attached to the main wing spar. The thrust chamber is canted downward at a 20 degree angle to protect the fuselage from excessive heat. The rocket oxidizer is contained in a low pressure aluminum tank located in the aft fuselage in place of the normal aft fuel cell. The oxidizer is delivered to the rocket pump by a submerged hydraulic boost pump in the bottom of the tank. The rocket fuel is drawn from the aircraft fuel system. The normal F-86E fuel boost pumps are replaced with pumps capable of low and high level operation. The high level fuel boost pump operation is necessary to provide adequate fuel pressure for rocket operation.

The pilot's controls consist of an arm switch and a fire switch. A ready light, a malfunction light, and a firing timer are also provided on the instrument panel. To fire the rocket, the pilot first closes the arm switch. After approximately 15 seconds, during which time the propellent lines are bled and various valves and controls are monitored for proper position, a green ready light illuminates and the fire switch is closed. Full thrust is obtained in approximately 2.5 seconds. The rocket can be shut down at any time by opening the fire switch. Six separate firings can be made within the duration of the propellent supply. If a malfunction should occur as a result of the rocket control system sensing a potentially unsafe condition, shutdown is accomplished automatically and the red malfunction light illuminates. The rocket will not refire after a malfunction shutdown.

Functional Analysis:
Several factors prevented a conclusive functional analysis: only one aircraft and one rocket were employed for the tests and only 23 operational tests were made; the duration of the test was too short to include a periodic inspection of the rocket or the airframe-rocket system; the aircraft and the rocket were maintained by contractor personnel at the contractor facility; and functional analysis was a secondary purpose of the test. Because of these factors this analysis should not be considered conclusive.

■ *Reliability:* The reliability of the YLR63-AJ-3 rocket appears to be superior to the LR63-AJ-1 and the YLR45-AJ-1 rockets tested previously by the Air Force. These earlier rockets were very similar in operation and design to the YLR63-AJ-3 and there is no readily apparent explanation for the significant difference in reliabilities. During the Air Force testing of the YLR63-AJ-3, 22 successful firings were obtained from 26 tests, which is a reliability of 85 percent. These figures include ground tests as well as in-flight tests. Considering in-flight tests only, the reliability of the rocket was 87 percent with 20 out of 23 tests being successful. All of the last 19 in-flight tests were successful. However, in view of the results of the Air Force tests of similar rockets, it is probable that a more extensive test of this rocket would show a lower reliability. The individual rocket tests are discussed in Appendix I.

■ *Fuel Boost Pumps:* The fuel boost pumps employed in the test aircraft were found to be deficient during rocket operation. These pumps are capable of a normal operating level for non-augmented flight and a high operating level (limited to 5 minutes duration) for rocket operation. Normally, at high operating level, the pumps supply fuel to the rocket pump at approximately 18 psig. Test data indicated that during various maneuvers the fuel pressure at the rocket pump dropped to as low as 2 psig. This results in approximately a 10 percent reduction in the rocket pump discharge pressure and a reduction in fuel flow rate. The resulting fuel-lean propellant mixture yields only a very small loss in thrust. However, this condition is undesirable because a pump suction pressure of 2 psig is near the minimum value for proper pump operation.

■ *Acid Venting:* The aft fuselage oxidizer tank vent system is unsatisfactory. The design of the vent system is such that acid is dumped overboard through the vent when the oxidizer tank is overfilled. When the acid will dump overboard is unpredictable. During this test, acid was observed venting at turbo-jet engine start and during taxiing. The oxidizer tank was intentionally overfilled for these tests but the method for servicing this tank makes it possible to inadvertently overfill at any time.

■ *Rocket Pod Fairing:* The forward section of the rocket pod fairing was extremely difficult to install. As fabricated, it did not clear the rocket assembly enough to allow installation. The points of contact with the rocket were relieved as much as possible; this allowed installation but it was still necessary to use a jack to force the fairing into position. The fairing will have to be redesigned before the installation will be acceptable.

■ *Accessibility of Components:* The accessibility of components in the YLR63-AJ-3 rocket has suffered from the severe weight and size design criteria imposed upon the rocket. Almost without exception, all the rocket components are difficult to maintain because of their location and closeness of the surrounding installation. Modification of the rocket with ease of maintenance as a prime consideration would result in a far more efficient weapons system.

■ *Deficiencies of Similar Rockets:* The Phase VI test of the LR63-AJ-1 ATO rocket installed on the F-84F aircraft revealed several major deficiencies that were not major problems during this test. Because of the similarity of the YLR63-AJ-3 and the LR63-AJ-1 rockets, however, there is no reason to believe that these problems would not become evident with more thorough testing. The following paragraphs describe three of these problems that are considered to be common to both of these rockets.

■ *Residual Acid Salting:* The Phase VI test of the LR63-AJ-1 rocket showed that during inactive periods when it was necessary to drain the normally-retained white fuming nitric acid from the rocket, the oxidizer system components are subject to fouling with residual acid salts. This condition proved to be a serious limitation during that test. The problem was not serious during the test of the YLR63-AJ-3, probably because there were few extended inactive periods when it was necessary to drain the acid from the rocket. Another probable explanation is that contractor personnel who were very familiar with the problems associated with liquid rockets maintained the rocket during the test.

■ *Oxidizer Line Deterioration:* Throughout the test of the LR63-AJ-1 rocket, many leaks developed in the oxidizer stainless steel lines as a result of acid-caused deterioration. Such leaks became more prevalent toward the end of the program as would be expected because of the aging of the system. Only two cases of oxidizer line leakage occurred during the test of the YLR63-AJ-3 rocket, both during the final week of testing. It is expected that this problem would increase greatly with the age of the installation.

■ *Trouble Shooting:* The LR63-AJ-1 field trouble shooting equipment and techniques were found to be extremely inadequate. During the Phase VI test of that rocket excessive time and effort were necessary to isolate causes of rocket malfunctions. In five instances, rocket instrumentation was needed to determine the difficulties. The YLR63-AJ-3 field trouble shooting equipment and techniques are essentially the same as those used for the LR63-AJ-1 and the rocket itself is substantially more complex. Therefore, it is believed that the YLR63-AJ-3 trouble shooting equipment and techniques would be unacceptable for operational use. This problem did not present itself during this test for several reasons: the rocket was instrumented and records were taken of every test; the test was brief and few rocket malfunctions were experienced; and rocket contractor personnel maintained the rocket.

■ *Personnel Requirements:* Rocket contractor maintenance personnel for the Air Force test of the YLR63-AJ-3 consisted of three rocket mechanics, one electrician, one instrumentation technician, and two rocket test engineers. These people were concerned with normal maintenance and servicing only. The normal aircraft maintenance crew maintained the airframe rocket system as well as the aircraft (the airframe rocket system is defined as the portion of the rocket installation fabricated by the airframe manufacturer). In an operational situation a maintenance crew of this size would not be necessary. An efficient operational maintenance crew would consist of the following:

1. Two rocket mechanics per aircraft to maintain the airframe rocket system as well as the rocket.

2. One rocket electrician per 12 aircraft.

3. One rocket contractor field service engineer per 12 aircraft.

4. Two 2-man rocket servicing crews per 12 aircraft. (One crew for acid servicing and one for UDMH and diluent servicing.)

5. The normal aircraft maintenance and support groups for aircraft maintenance only.

Satisfactory maintenance of the rocket could be accomplished by average maintenance personnel provided they receive specialized schooling as well as on-the-job training. However, contractor guidance during trouble shooting will undoubtedly be necessary. It is likely that under operational conditions very little trouble shooting would be attempted with a rocket installed on an aircraft. A malfunctioning engine would be replaced and trouble shooting accomplished on a static test stand. Approximately four men would be required to operate and maintain such a test stand.

■ *Man-hour Requirements:* During this test approximately 18 man-hours of rocket maintenance and servicing were required for each successful in-flight rocket firing. A more efficient maintenance crew size may have resulted in a lower man-hour per firing requirement; however, this expenditure is still considerably less than the 23 man-hours per rocket firing found to be necessary to maintain the LR63-AJ-1 rocket on the F-84 aircraft. This difference can be explained by the following: approximately 25 percent of the total man-hour expenditure for the YLR63-AJ-3 test was unscheduled rocket maintenance while over 60 percent of the maintenance of the LR63-AJ-1 was unscheduled; a periodic rocket inspection was not included in the test of the YLR63-AJ-3; and, the scheduled maintenance during this test was probably more brief than that which would meet Air Force standards. It is probable that between 20 and 25 rocket maintenance man-hours would be required for each in-flight firing in an operational situation.

Approximate time and personnel requirements to accomplish various phases of scheduled maintenance of the YLR63-AJ-3 rocket installed on the F-86E aircraft are presented below.

ROCKET SYSTEM REQUIREMENTS

Function	Hours Required	Number Men Required
Pre-flight insp.	½	2
Post-flight	1	2
Periodic insp.	24	2
Turnaround time	1½	2

■ *Acid Handling:* No problems were encountered in the handling, storage or shipping of the white fuming nitric acid used in this flight test. The acid was stored and shipped in 50-gallon aluminum drums and pumped directly from the drums through a sintered stainless steel filter to the rocket oxidizer tanks. This procedure apparently did not jeopardize ground safety and excessive acid contamination was not detected.

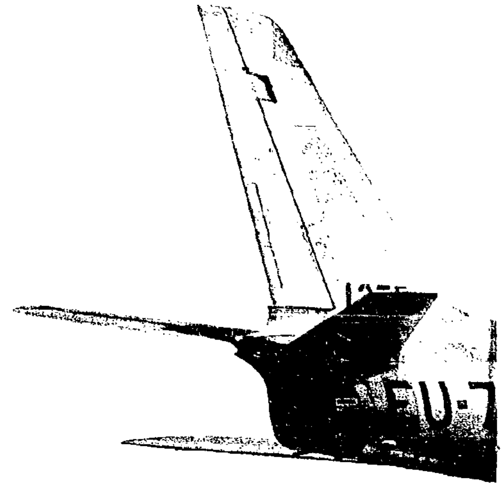
Full protective suits, including hoods and gloves, were worn by the maintenance personnel during acid servicing and when working on or near the rocket when the oxidizer system was pressurized. An emergency decontamination shower as well as a water supply for routine or emergency use was located at the aircraft preparation site. No accidents involving white fuming acid were experienced during the test.

The Air Force test of the LR63-AJ-1 rocket indicated that periodic warnings were necessary to caution personnel about unsafe habits and practices. Unsafe practices tended to develop after personnel became familiar with maintenance operations and employed short cuts to accomplish tasks. Since the protective clothing is extremely uncomfortable, particularly in hot weather, maintenance personnel had to be cautioned regularly to wear at least gloves and protective hoods when performing the less hazardous tasks.

■ Intercept capabilities

As a research vehicle, this aircraft proved the idea of thrust augmentation for super performance to be good. The reduction in time to climb, the increased operational altitudes, and the improved dash capabilities are evident. The maintenance and support requirements are high, but may not be prohibitive if a super performance weapon is required. The questions that remain are: (1) is the augmented performance usable? and (2) are the gains with augmentation worth the losses connected with the system?

Assuming a maximum range intercept at 50,000 feet under GCI control, the augmented aircraft would meet the target 132 miles from base at a Mach number near 1.0, using the technique of firing the rocket at about 40,000 feet, climbing to 50,000 feet, and leveling off while in augmented flight. The elapsed time since take-off would be 18.1 minutes. Thirty seconds of augmented flight would remain for the attack. Under optimum conditions, return to base would be possible with the remaining 580 pounds of fuel.



Two GCI intercept flights were made by the APGC pilot during the tests. In the first intercept, the rocket was fired at 30,000 feet for a lead-collision attack on a target (F-86) at 40,000 feet. The attack was considered successful even though it was not started from an optimum lateral position. The second was intended to simulate the attack phase of the above maximum range intercept at 50,000 feet but the target (F-100) was unable to maintain 50,000 feet. The rocket was fired at 39,000 to 40,000 feet at a range of approximately 5 miles. The attack was considered successful with rocket burn-out well past the target at 47,000 feet. Radar tracking was considered possible.

Except for the reduced total range, the augmented aircraft is superior to the standard model, since the accumulated losses in military power performance can be more than regained at any time with augmentation.

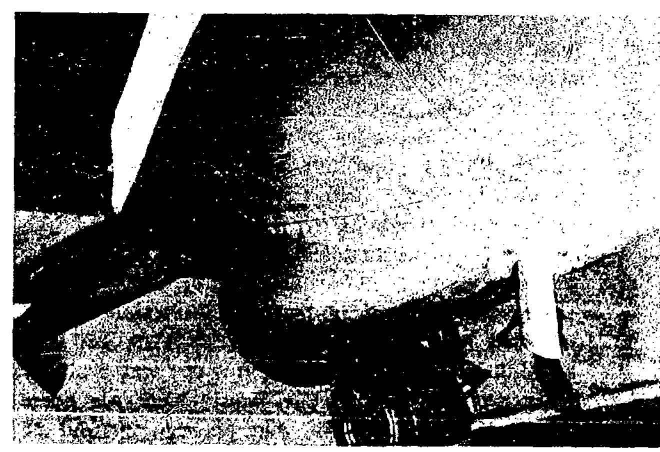
Although intercept missions are possible which are beyond the capabilities of the standard aircraft, several improvements could be made which would increase the performance of the system:

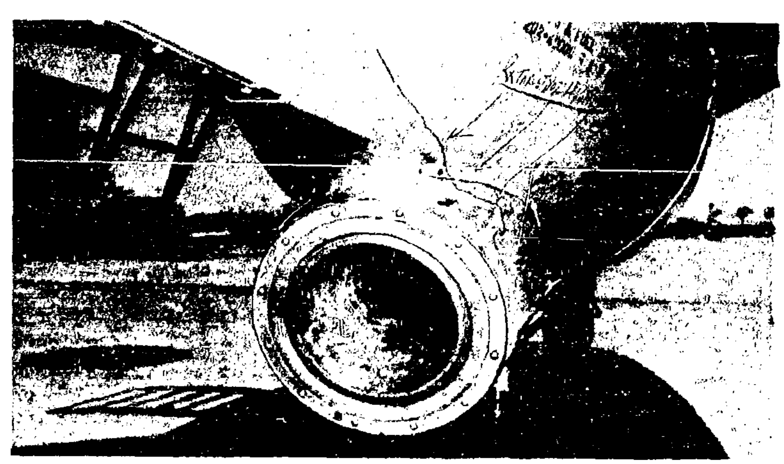
1. The installation should be buried in the tail to reduce both drag and pitching moments. This has been done in the F-84F and the FJ-4 (Reference 4).

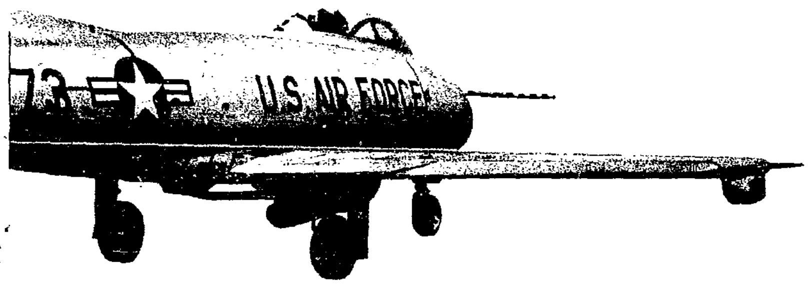
2. The thrust output should be variable to permit better utilization (Reference 5).

3. The duration should be increased. The system was limited by oxidizer supply, not thrust chamber (Reference 5).

4. More thrust could be used. Additional thrust is available in this and other rockets (Reference 5).







CONCLUSIONS

1. The addition of a thrust augmentation device to an F-86E aircraft produces high performance for a short duration.

2. Advantages of rocket augmentation of the F-86E aircraft area:

a. The climb performance is considerably improved. At any altitude, a potential of approximately 14,000 feet of altitude exists in the 70 second time duration of rocket burning.

b. Level acceleration, speed, maneuvering flight, and dash capabilities are markedly improved.

c. Accumulative performance losses sustained under main engine power due to increased weight and drag can be more than recovered by using augmentation.

d. Within a limited radius, point intercept missions are possible at a speed and altitude which are beyond the capability of the standard F-86E aircraft.

e. With specialized training, maintenance is within the scope of Air Force personnel.

3. Disadvantages of the rocket installation in the F-86E aircraft are:

a. With the rocket system ready, but not operating, performance is reduced in all categories. Predominant performance losses are:

(1) Time to climb to any altitude is increased approximately 50 percent.

(2) At maximum range power settings at 35,000 feet, true airspeed is reduced 6 percent and specific range is reduced 13.8 percent. The total range is further reduced by the replacement of 105 gallons of internal fuel with oxidizer.

b. Maintenance requirements based on limited data are high, but are not necessarily prohibitive. Contractor field service engineers are required for trouble shooting.

4. White fuming nitric acid handling can be accomplished in a safe, routine manner by properly trained and equipped personnel; however, periodic instruction and constant supervision are necessary to insure that personnel do not become overconfident and begin short cutting safety procedures. Acid contamination control and detection do not constitute a major problem provided the correct handling procedures are followed.

5. The reliability of 87 percent is considered good for the present development state of the art, but marginal for operational use.

6. The point intercept capabilities of present and future weapon systems could be increased by the use of rocket thrust augmentation.

RECOMMENDATIONS

1. It is recommended that any future interceptor rocket installation be designed to include the following features:

a. A buried installation to reduce drag and pitching moments and to provide maximum aircraft performance during the rocket run.

b. At least 2 minutes total rocket run time with variable thrust and re-lights possible to allow variable and optimum use of the augmented performance.

c. An augmented thrust-to-weight ratio at least as high as it was for this test.

2. It is recommended that the following refinements be made in the present installation before extensive use:

a. The system operating reliability be further improved.

b. Fuel boost pumps that provide adequate fuel pressure during any maneuver be employed.

c. The possibility of inadvertent overfilling of the oxidizer tank and subsequent dumping of acid be eliminated.

d. The rocket pod fairing be redesigned to allow easy installation.

e. The accessibility of rocket components be improved.

f. A technique be developed to prevent residual acid salting of rocket components.

g. A different material or heavier gage tubing be utilized for oxidizer lines to improve durability.

h. More adequate field trouble shooting techniques and equipment be developed.

APPENDIX I

individual rocket test firings and rocket system parts consumption

■ individual rocket test firings

The Air Force test of the YLR63-AJ-3 rocket consisted of 33 rocket tests utilizing one rocket assembly. Twenty-three were in-flight tests and three were static ground firings. The remaining seven tests (tests number 2, 4, 5, 6, 7, 9, and 26) were rocket gas generator tests only.

■ *Test number 1:* The first test was an attempted in-flight rocket firing and resulted in a rocket malfunction. Investigation revealed that the rocket starter valve had seized in the open position, preventing normal rocket operation. The cause of the seizure was found to be a mechanical cocking of the valve as a result of under-torquing assembly bolts during the factory assembly. The valve was replaced.

■ *Test number 3:* The next attempted rocket firing was a static ground test. This test also resulted in a rocket malfunction. The test data indicated that during the rocket starting cycle the thrust chamber pressure was below a safe minimum for continued operation. The rocket controls under this condition initiated a safe shutdown at that point. It was determined that this rocket malfunction was caused by the restriction of propellent flow into the rocket starter chamber by foreign material. The foreign material was removed by pickling the starter chamber in a solution of dilute nitric acid.

■ *Tests 8 and 10:* Test number 8 was a short aduration static ground firing made to check the rocket thrust level. The thrust was below the desired level and could not be adjusted to the desired level because the rocket turbine pump was not providing adequate propellent discharge pressures. The turbine pump assembly was replaced and a second static ground firing, test number 10, was conducted. The test was successful and the rated thrust was attained.

■ *Test number 11:* On 12 October 1956, the second in-flight rocket test was attempted and again a malfunction shutdown resulted. Test data indicated that the shutdown was due to the rocket control system sensing an over-temperature condition in the gas generator combustion chamber; however, investigation revealed that an over-temperature condition did not exist but that the over-temperature switch was vibration sensitive. Test number 5, a gas generator test, also ended with a malfunction due to an indicated over-temperature condition. The possibility that the over-temperature switch was vibration sensitive was not considered at that time; however, both of these malfunctions are now attributed to vibration. The over-temperature switch was replaced prior to test number 12, which was a satisfactory in-flight firing. This malfunction did not recur.

■ *Test number 13:* This test resulted in a rocket malfunction. The cause of the malfunction was not definitely established but it is believed that during the pre-flight inspection the connector between the aircraft and the rocket electrical systems was not sufficiently tightened to provide positive circuit continuity.

■ *Tests 14 through 33:* Excluding test 26, which was a gas generator test, the remaining tests were in-flight rocket firings and all were successful.

parts consumption

Rocket System Part Number	Description	Consumed
2-000106	Valve, oxidizer tank bleed	3
2-001016	Assembly, turbine pump	1
2-001270	Regulator, actuation air	1
2-002139	Cover, oxidizer filter case	1
2-002406	Assembly, gas generator	1
2-002501	Pod tank, hypergolic	1
2-002542	Pod tank, diluent	1
2-002629	Pod tank, oxidizer	1
2-002805	Sleeve, GG-TPA	1
2-002903	Bellows, oxidizer line	1
2-003730	Valve, starter	1
2-004113	Venturi, oxidizer	1
2-005257-2	Valve, duplex check	1
2-009947	Cross, oxidizer drain	1
2-011305-2	Valve, thermal relief	1
2-011664	Switch, over-temperature	2
2-39370	Assembly, oxidizer filter	1
220A-4TT	Valve, diluent bleed check	2
220T3-4TT-TA	Valve, oxidizer bleed check	2
SH1168-1	Diaphragm, AAR burst	2

APPENDIX II

test techniques and data analysis methods

bibliography

1. Phase IV Flight Test of F-86E Aircraft, USAF No. 50-582. Wm. M. Magruder. 18 June 1952.

2. T.N. 3526, Flight Calibration of Four Airspeed Systems on a Swept-Wing Airplane at Mach Numbers up to 1.04 by the NACA Radar-Phototheodolite Method. Thompson, Bray and Cooper. November 1955.

3. AFTR 6273, Flight Test Engineering Manual (Revised). May 1951.

4. PPD Rpt. No. NA 56H-54-5. Study of the NAA AR-1 Rocket Engine Installation in the FJ-4R Airplane. M. W. Bell North American Aviation Inc. 16 April 1956. (Confidential)

5. YLR63-AJ-3 IFTA Rocket. Aerojet-General Corporation. 1 November 1956. (With discussion of XLR73 Rocket.) (Confidential)

recording of data

A photo panel and an oscillograph were used to record the necessary aircraft parameters. Airspeed, altitude, rpm, fuel count, time, and tailpipe temperature were lead to the photo panel; vertical acceleration, stabilizer position, battery voltage, aileron position, tailpipe total pressure, longitudinal stick force, rocket run time, and various temperatures including OAT and skin temperatures to the oscillograph. A second oscillograph recorded rocket parameters.

In reducing the static thrust run it was found that a tailpipe total pressure transducer of too small a sensitivity had been installed. The instrument specifications were consulted and the proper type transducer was calibrated and installed. The results obtained with this transducer were not usable although instrumentation personnel of the AFFTC and at North American Aviation Incorporated were consulted and the transducer re-calibrated (same calibration). Also, during the test flights, the stepping box for the oscillograph channel which recorded OAT rarely got to the OAT position during a data shot. Balloon data was used for obtaining free air temperature. Balloon data was also used for obtaining winds during the climb tests.

thrust calibration

The methods and theory of section 3, reference 3, were used to correct the data from the static thrust run.

thrust corrections

Where thrust or engine rpm corrections were necessary, a ram efficiency of 95 percent was assumed and engine curves of Fn/δ_{t_2} versus $N/\sqrt{Ta}$ for the J47-GE-13 engine were used. When non-standard test altitudes required corrections to rocket thrust, Figure 20 of this Appendix (or derivatives from it) were used.

climbs

Because of the 105 gallon reduction in internal fuel capacity it was necessary to carry and drop one 120-gallon external tank on all flights with tests starting higher than 30,000 feet. No tests were made with the tank in place. Military power climb data was obtained in continuous climbs from field elevation to 20,000 or 30,000 feet and in partial climbs to higher altitudes after the tank was dropped for high altitude tests. Augmented climb data was obtained during continuous climbs from 20,000 feet and from approximately 41,000 feet. The climb schedules were estimated from previous F-86E and F tests and were checked early in the program during level accelerations.

The analysis methods of section 5, reference 3, were used by the Data Reduction Branch with a few notable exceptions: (1) Fn/δ_{t_2} was used for thrust corrections to rate of climb, (2) a test curve of $\Delta\left(T_{t_6}/\theta_{t_2}\right)/\Delta(N/\sqrt{\theta_{t_2}})$ versus $N/\sqrt{\theta_{t_2}}$ was used to correct to standard tailpipe temperatures, and (3) any resulting over-temperature was reduced to limit temperature with resulting reduction in rpm and rate of climb. No corrections were required for non-standard rocket conditions.

accelerations

Military power accelerations were made at 20,000, 30,000 and 40,000 feet, followed immediately (in most cases) by an augmented acceleration from the same starting airspeed. A starting speed was selected which would (1) define the speed for best climb, (2) not require excessive time and fuel to reach desired speeds, and (3) assure attaining maximum level flight speed with augmentation.

The reduction to standard conditions by the Data Reduction Branch was based on a conversion of horizontal acceleration to potential rates of climb. Corrections to this dH/dt were then made similar to those for climbs. The resulting standard rate of climb for each point was then re-converted to a standard acceleration. The basic equations which differ from those used for climb analysis are as follows:

$$R/C_{STD} = dH/dt + \Delta R/C + \Delta R/C_1 + \Delta R/C_3 + \Delta R/C_{RX}$$

$$dH/dt = 60 \left[\frac{19362\theta_{a_s}\left(M_{i+n}^2 - M_i^2\right) + \left(Hp_{i+n} - Hp_i\right)}{t_{i+n} - t_i}\right] \text{ ft./min.}$$

where i : 1st point
i+n : 4th point (in this case)

$\Delta R/C_{RX} = \left(\frac{\Delta R/C}{\Delta K}\right) \times \Delta K_{RX}$, a correction for rocket thrust for being off standard altitude.

where $\Delta H = H_{p_t} - H_{p_s}$

$$\Delta F = \left(\frac{\Delta F}{\Delta H}\right)_{RX} \times \Delta H$$

$\Delta K_{RX} = \Delta F \times \frac{1}{\delta_{t_2 \, engine}}$, converting the correction to a form similar to that for a turbo-jet engine. The resulting standard rates of climb are then re-converted,

$dV/dt_{STD} = R/C_{STD} \times 0.1882/V_{T_{S_{ave}}}$, $K_N/SEC.$

where R/C_{STD} : ft./min.

V_{T_S} : Kn, true airspeed

These standard rates of acceleration were then numerically integrated to give standard day acceleration time histories.

The original plan for evaluation of pitch problems with rocket operation was to measure longitudinal stick force from trim required to counteract the pitching tendencies. This method was discarded and measurement of elevator deflection was used after the first few rocket runs showed the aircraft trim changes to be too great for smooth flight at original trim. The program pilots eventually developed a technique of hitting trim during the rocket starting delay to meet the pitch-up as it occurred.

maneuvering flight

Level wind-up turns were made with both military power and with military plus augmentation at 30,000 and 40,000 feet. The military power turns were started from a speed near maximum level flight speed and were continued in a single turn on the stall boundary as the speed decreased. Because of total data time restrictions, periodic data shots rather than continuous recording were used. The augmented turns were started after a short level flight acceleration to a Mach number near 0.9. The subsequent wind-up on the stall boundary was continued, with continuous recording, to rocket burn-out. It was expected and found that a more or less stabilized condition was reached where the aircraft was flying at constant airspeed on the stall boundary. This restricted the data to a fairly narrow band of Mach numbers.

The resulting data from both types of turns at a given altitude were reduced to a common standard altitude and weight by assuming that the coefficient of lift for each data point remained the same as the point was corrected.

$$CL_{t_{apparent}} = \frac{.00675 \, n_t W_t}{M_t^2 \, S \, \delta_t}$$

$$N_S = \frac{C_{L_t} M_t^2 S}{.000675 (W/\delta)_S} = n_t \times \frac{(W/\delta)_t}{(W/\delta)_s}, \text{ G}$$

The term "apparent coefficient of lift" is used because of the small error in test Mach number resulting from the use of non-accelerated airspeed calibration data.

No thrust corrections were made. Standard maneuvering capabilities were then obtained from curves of rate and radius of turn versus true airspeed based on the following equations.

$$\Delta t_{360°} = \frac{V_{T_S}}{\sqrt{9.2\,(n_S^2-1)}}, \text{ sec.}$$

where V_{T_S} : K_N., at test Mach and standard altitude

$$\omega_S = \frac{360}{\Delta t_{360°}}, \text{ deg/sec.}$$

$$r_S = \frac{V_{T_S} \times 0.0159}{\omega_S}, \text{ N.M.}$$

The data from F-86E No. 582 was corrected only for airspeed and altitude errors.

unaugmented level flight

Speed-power-fuel data was obtained near 35,000 feet at a pre-calculated value of W/δ which simulated flight with all rocket fluids aboard. Speed-power points were also derived from a series of short-duration airspeed calibration points at 20,000 feet. The analysis methods of section 4, reference 3 were used except that no corrections were required for non-standard values of W/δ (the polar of a previously tested F-86F with the same 6 x 3 wing was used to check for W/δ correction requirements). The test curve of $W_t / \sqrt{\theta_{t_{2_t}}}\ \delta_{t_{2_t}}$ versus $N_t / \sqrt{\theta_{t_{2_t}}}$ which was used to correct fuel flows at 35,000 feet is shown in Figure 17 of this Appendix.

airspeed calibration

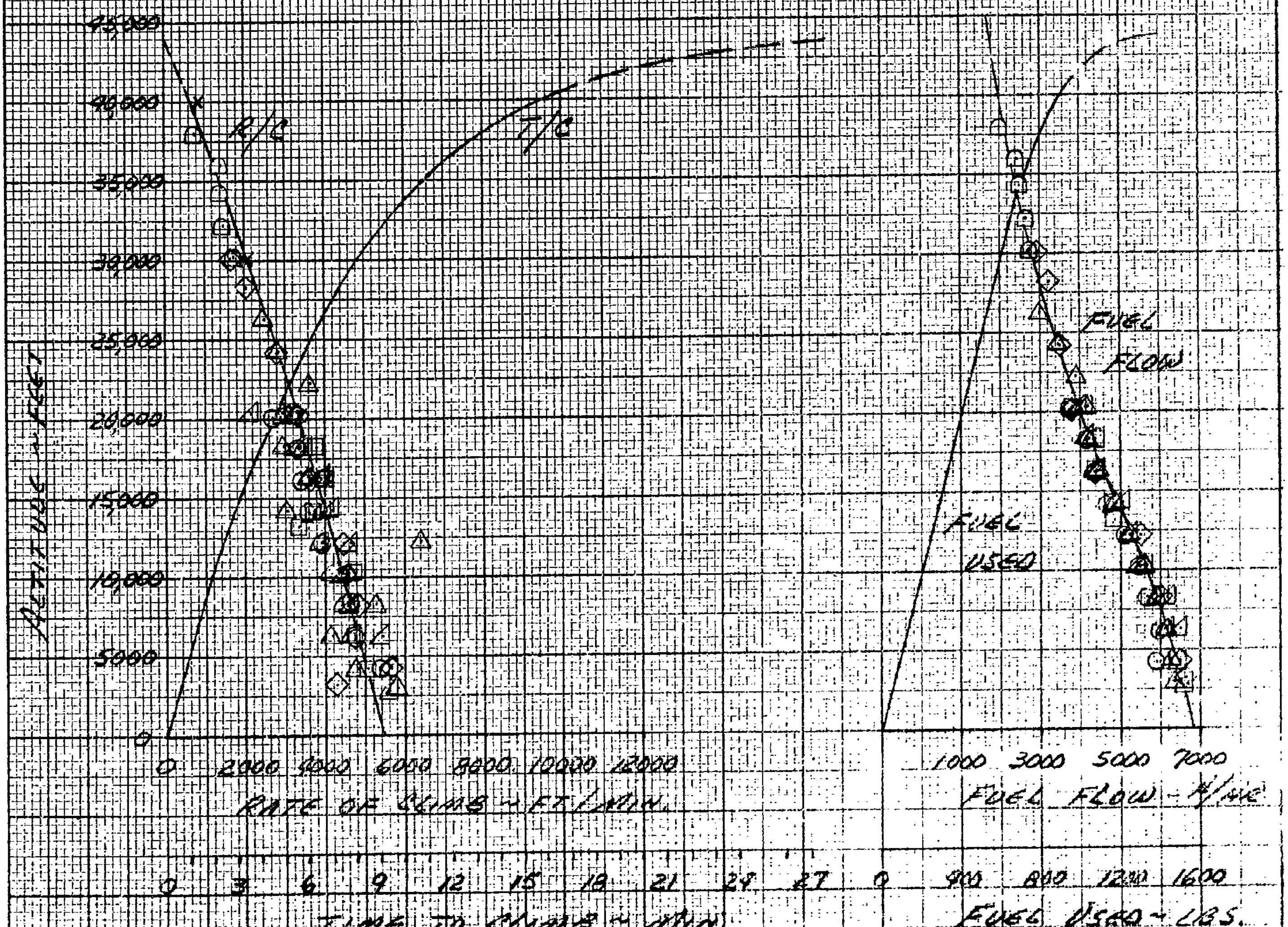
Airspeed calibration points were obtained in stabilized flight at 12,000, 20,000 and 40,000 feet. An attempt was made to obtain points at higher speeds by using a pacer-laid contrail for the augmented acceleration at 40,000 feet. Pitch-up problems destroyed the accuracy of this attempt but still allowed use of the data to establish the trend of the position error correction. The methods of section 1, reference 3, were used in reducing the data for the speed range covered. Reference 2 was used to extrapolate the curves to the maximum Mach numbers expected to be encountered.

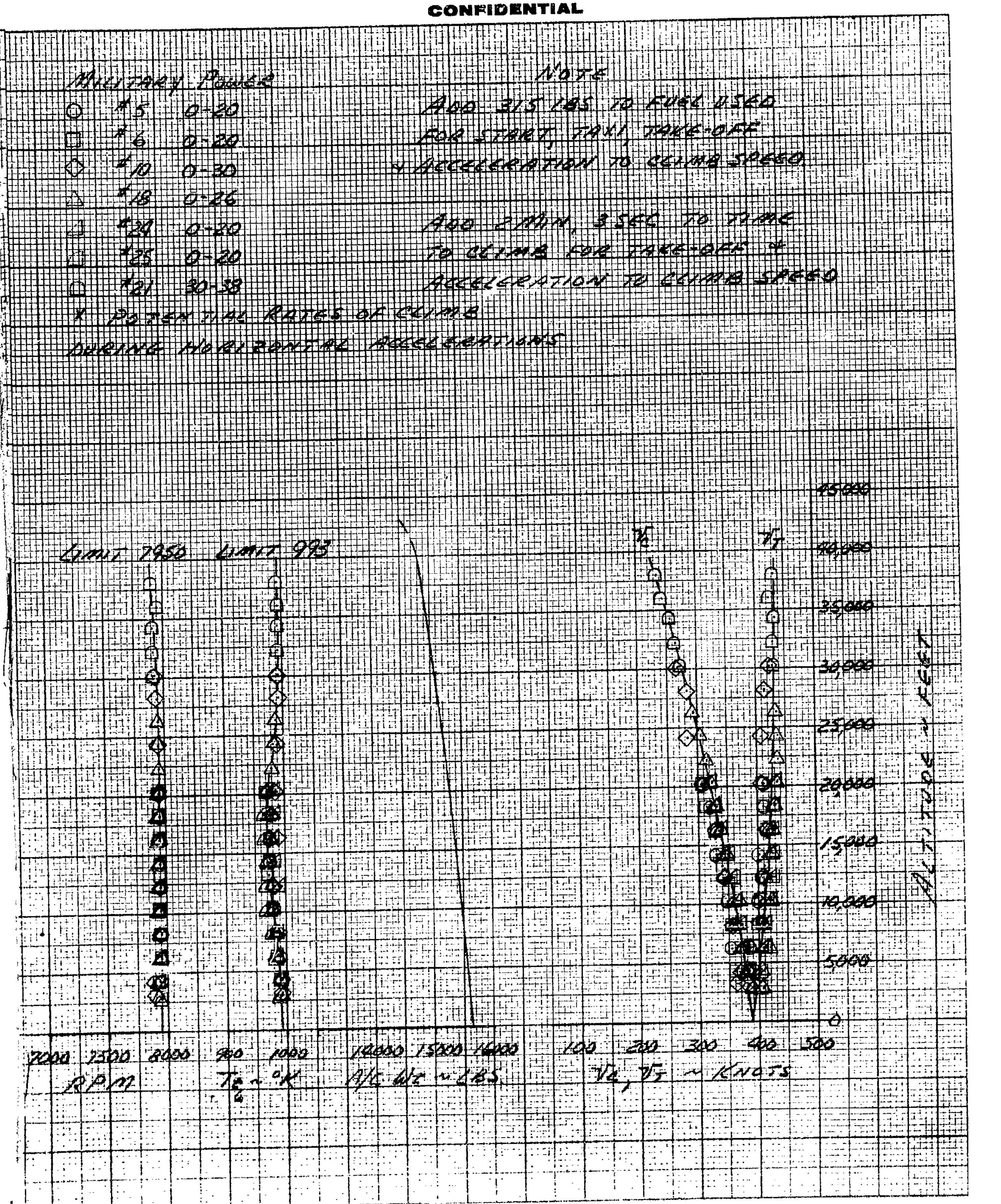
performance data

FIGURE NO. 1

CLIMB PERFORMANCE
F-86E USAF No 51-2773
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
15,984 LBS. AT ENGINE START

MILITARY POWER
INLET SCREENS IN PLACE




MILITARY POWER
○ #5 0-20
□ #6 0-20
◇ #10 0-30
△ #18 0-26
#24 0-20
#25 0-20
#21 30-38
X POTENTIAL RATES OF CLIMB
DURING HORIZONTAL ACCELERATIONS
NOTE
ADD 315 LBS TO FUEL USED
FOR START, TAXI, TAKE-OFF
+ ACCELERATION TO CLIMB SPEED.
ADD 2 MIN, 3 SEC TO TIME
TO CLIMB FOR TAKE-OFF +
ACCELERATION TO CLIMB SPEED
LIMIT 7950
LIMIT 993
V_C
V_T
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5000
0
ALTITUDE ~ FEET
7000 7500 8000
900 1000
14000 15000 16000
100 200 300 400 500
RPM
T_4 ~ °K
A/C WT ~ LBS.
V_C, V_T ~ KNOTS

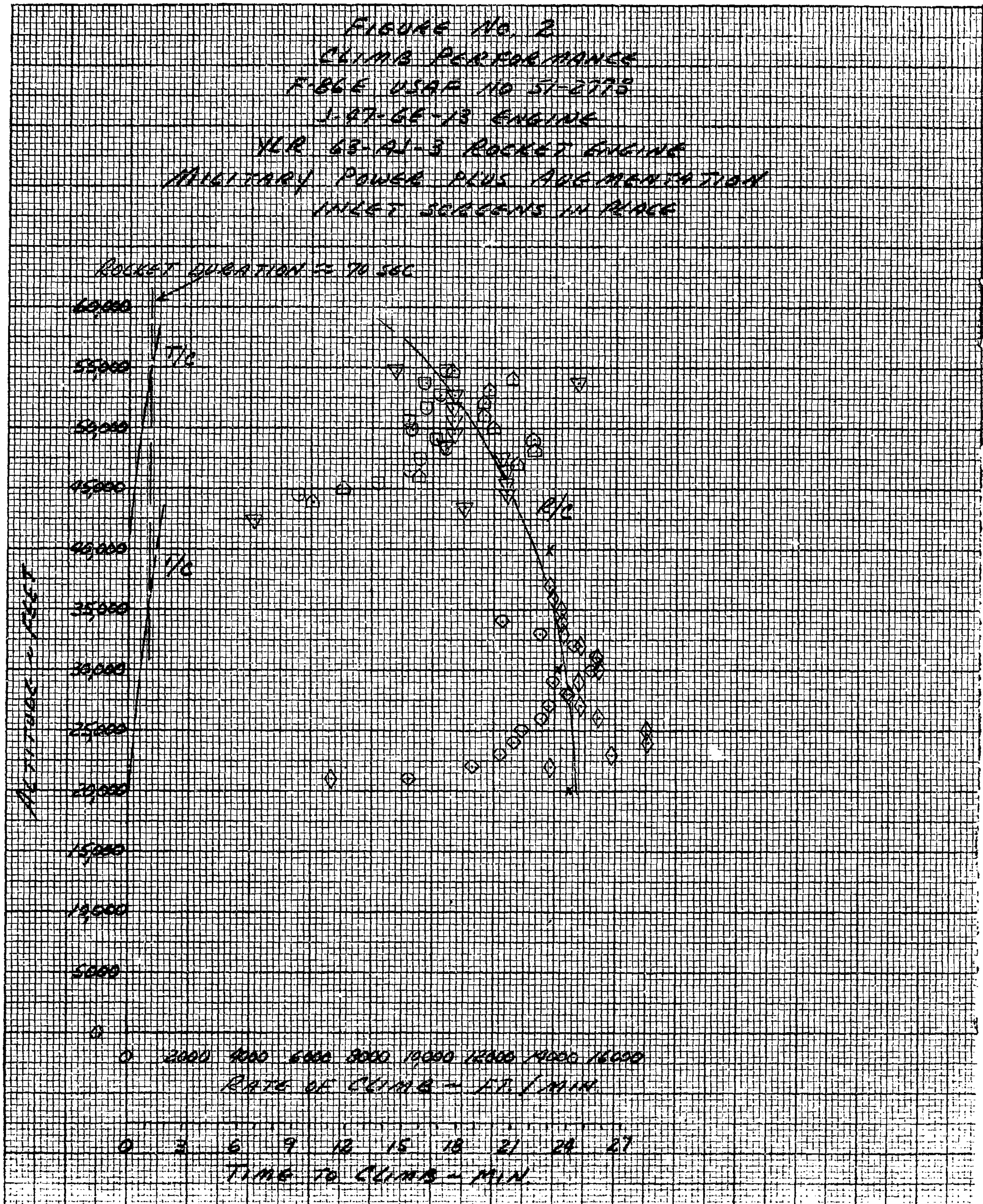


FIGURE NO. 2
CLIMB PERFORMANCE
F-86E USAF NO
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
MILITARY POWER PLUS AUGMENTATION
INLET SCREENS IN PLACE
ROCKET DURATION = 70 SEC
T/C
R/C
ALTITUDE ~ FEET
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5000
0
0 2000 4000 6000 8000 10,000 12000 14000 16000
RATE OF CLIMB ~ FT./MIN.
0 3 6 9 12 15 18 21 24 27
TIME TO CLIMB ~ MIN.

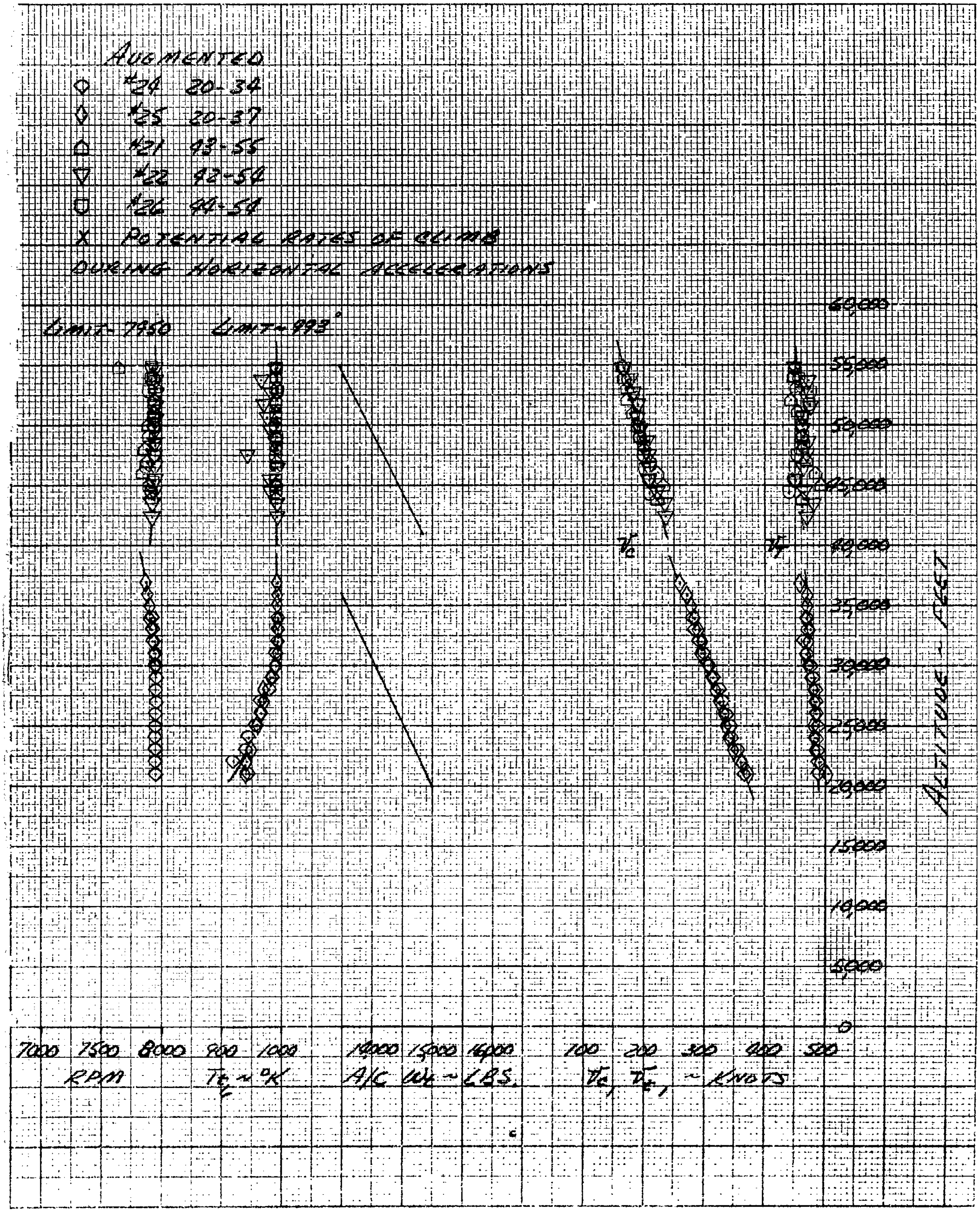
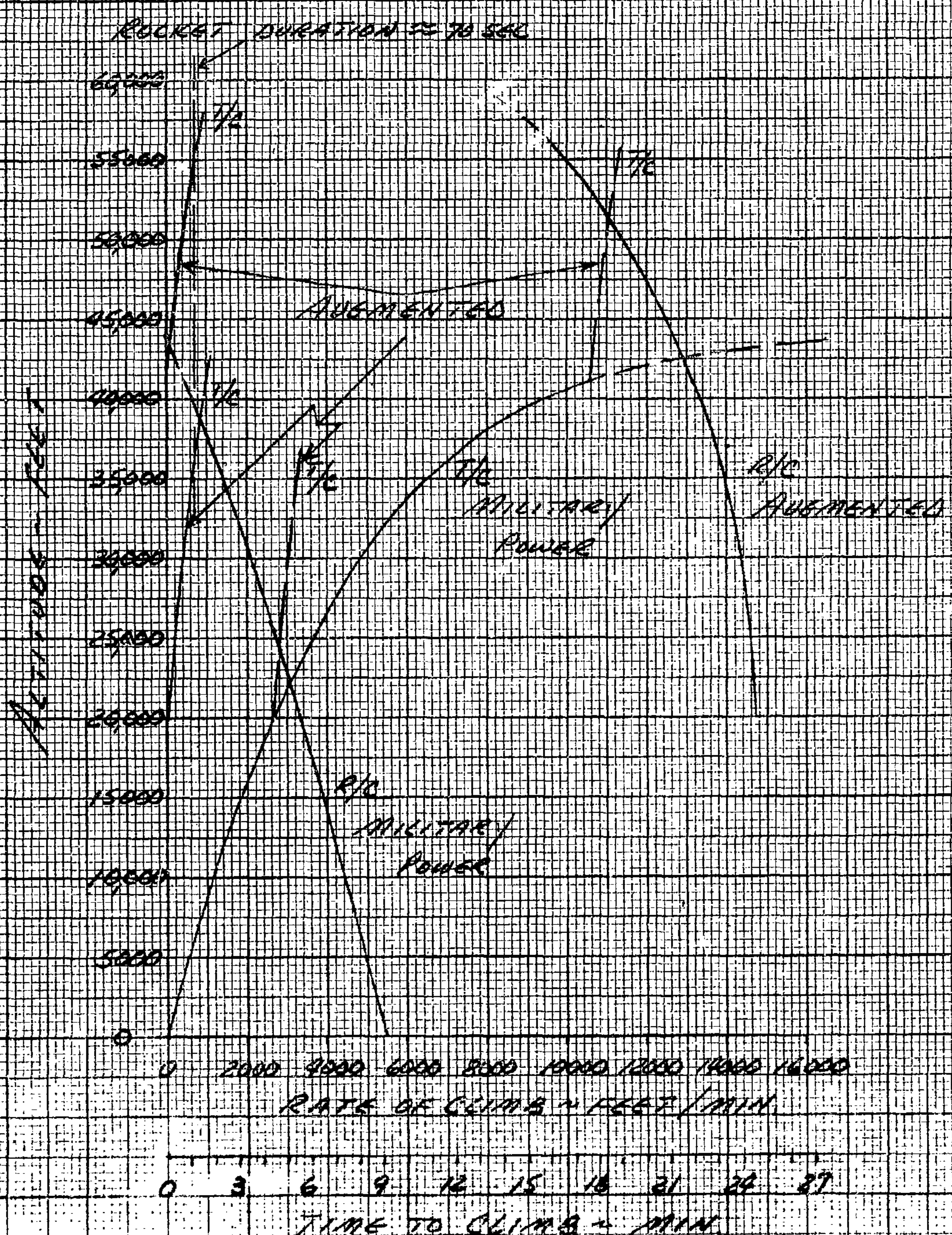
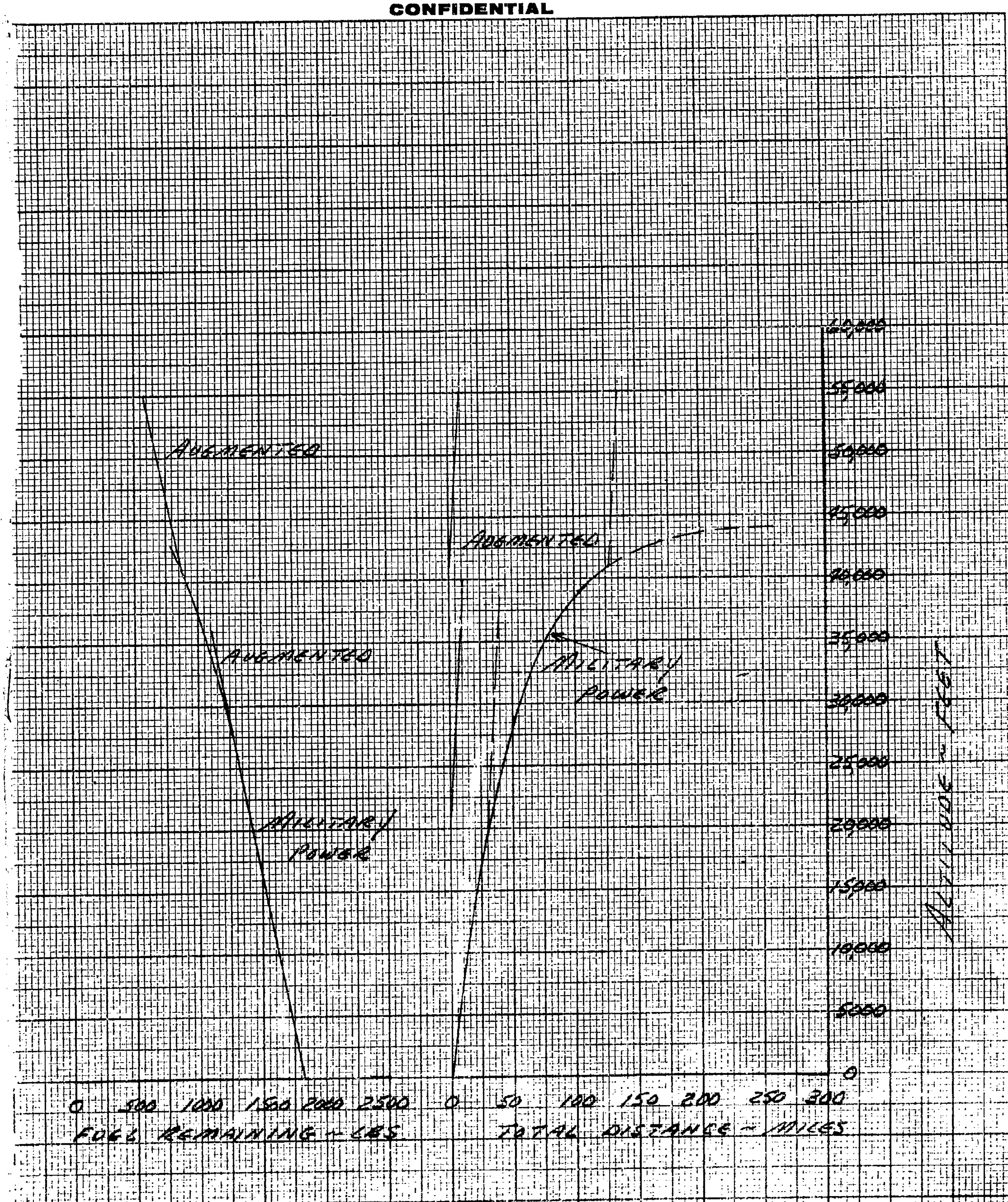

AUGMENTED
#24 20-34
#25 20-37
#21 43-55
#22 42-54
#26 44-54
X POTENTIAL RATES OF CLIMB DURING HORIZONTAL ACCELERATIONS
LIMIT-7950
LIMIT-993°
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5000
0
ALTITUDE ~ FEET
7000 7500 8000
RPM
900 1000
T_{t_4} ~ °K
14000 15000 16000
A/C Wt ~ LBS.
100 200 300 400 500
V_c, V_{t}, ~ KNOTS

FIGURE No. 3
COMBINED CLIMB PERFORMANCE
F-86F USAF No. 51-2773
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
15,924 LBS AT ENGINE START
INLET SCREENS IN PLACE





AUGMENTED
AUGMENTED
MILITARY POWER
AUGMENTED
MILITARY POWER
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5000
0
0 500 1000 1500 2000 2500
FUEL REMAINING ~ LBS
0 50 100 150 200 250 300
TOTAL DISTANCE ~ MILES
ALTITUDE ~ FEET

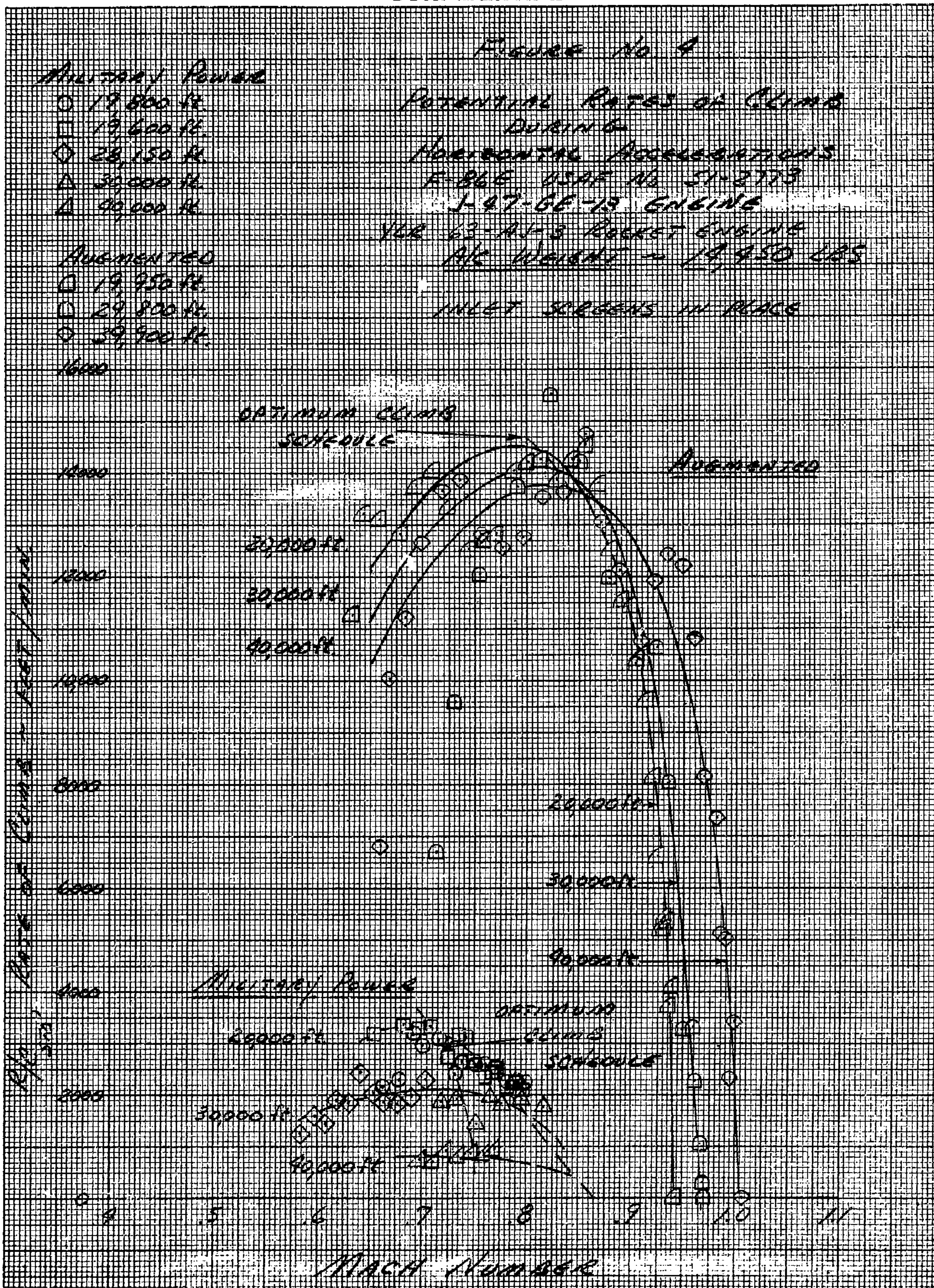
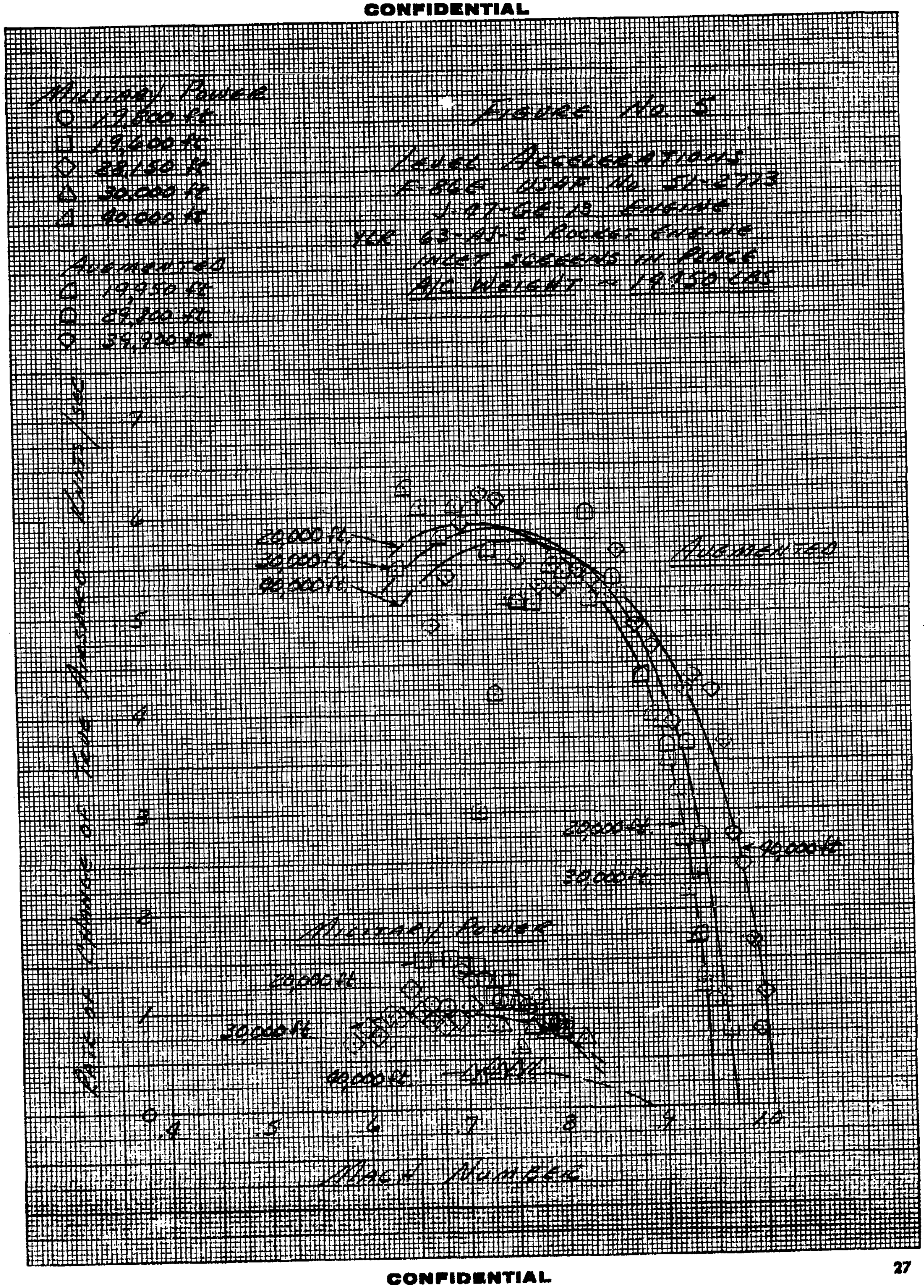


FIGURE No 4
POTENTIAL RATES OF CLIMB
DURING
HORIZONTAL ACCELERATIONS
F-86E USAF No 51-2773
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
AK WEIGHT ~ 14,450 LBS
INLET SCREENS IN PLACE
MILITARY POWER
19,800 ft.
19,600 ft.
28,150 ft.
30,000 ft.
40,000 ft.
AUGMENTED
19,950 ft.
29,800 ft.
39,900 ft.
16000
14000
12000
10000
8000
6000
4000
2000
OPTIMUM CLIMB SCHEDULE
AUGMENTED
20,000 ft.
30,000 ft.
40,000 ft.
MILITARY POWER
OPTIMUM CLIMB SCHEDULE
.4
.5
.6
.7
.8
.9
1.0
1.1
MACH NUMBER
RATE OF CLIMB ~ FEET/MIN.


Military Power
19,800 ft
19,400 ft
28,150 ft
30,000 ft
40,000 ft
Augmented
19,950 ft
29,800 ft
39,900 ft
Figure No. 5
Level Accelerations
F-86E USAF No. 51-2773
J-47-GE 13 Engine
XLR 63-AJ-3 Rocket Engine
Inlet Screens in Place
A/C Weight ~ 19,150 lbs
Rate of Change of True Airspeed - Knots/sec
Augmented
Military Power
20,000 ft
30,000 ft
40,000 ft
Mach Number

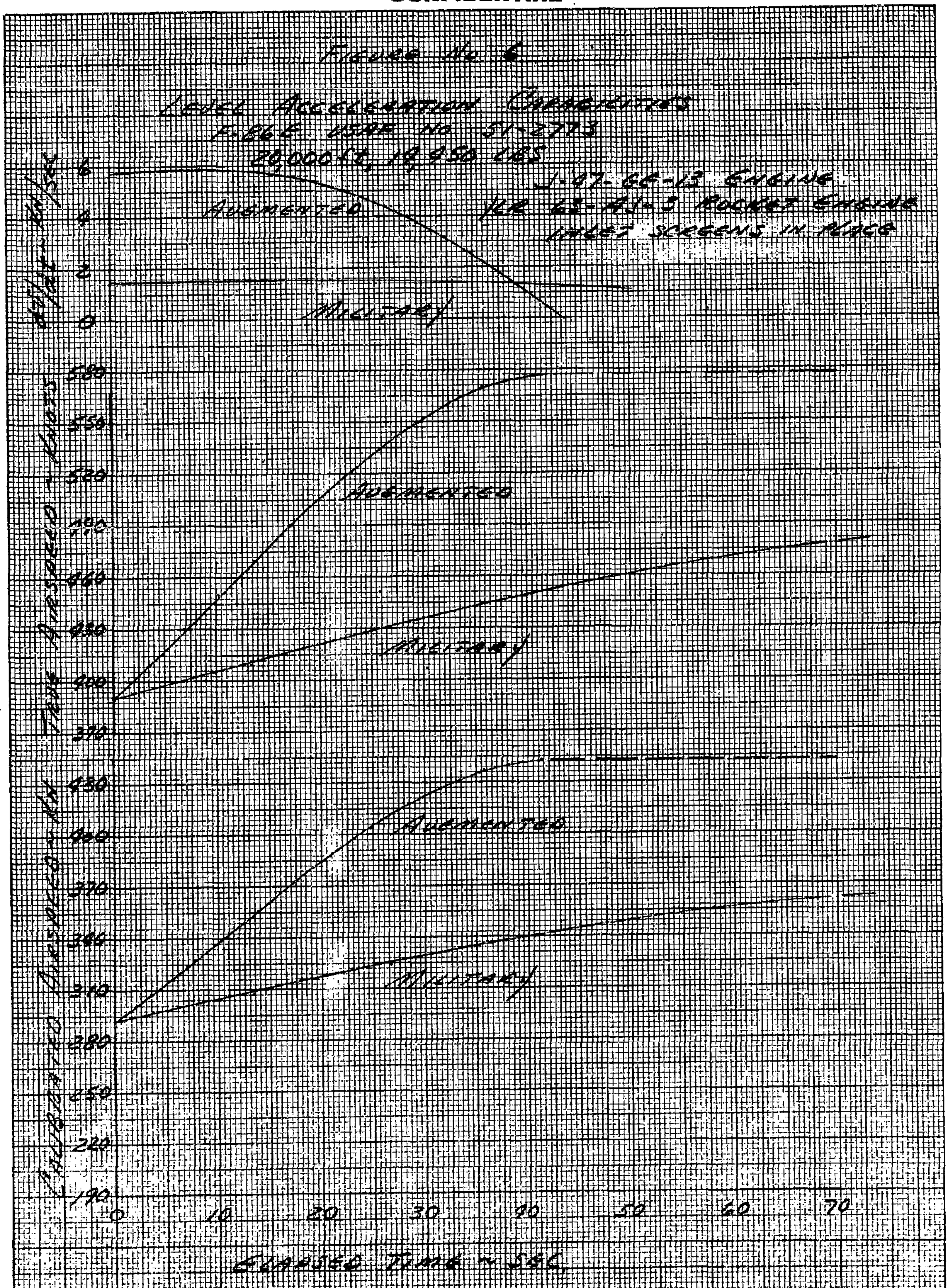


Figure No. 6
Level Acceleration Characteristics
F-86E USAF No. 51-2773
20,000 ft, 14,950 LBS
J-47-GE-13 Engine
XLR 63-AJ-3 Rocket Engine
Inlet Screens in Place
Augmented
Military
Augmented
Military
Augmented
Military
0
10
20
30
40
50
60
70
Elapsed Time ~ Sec

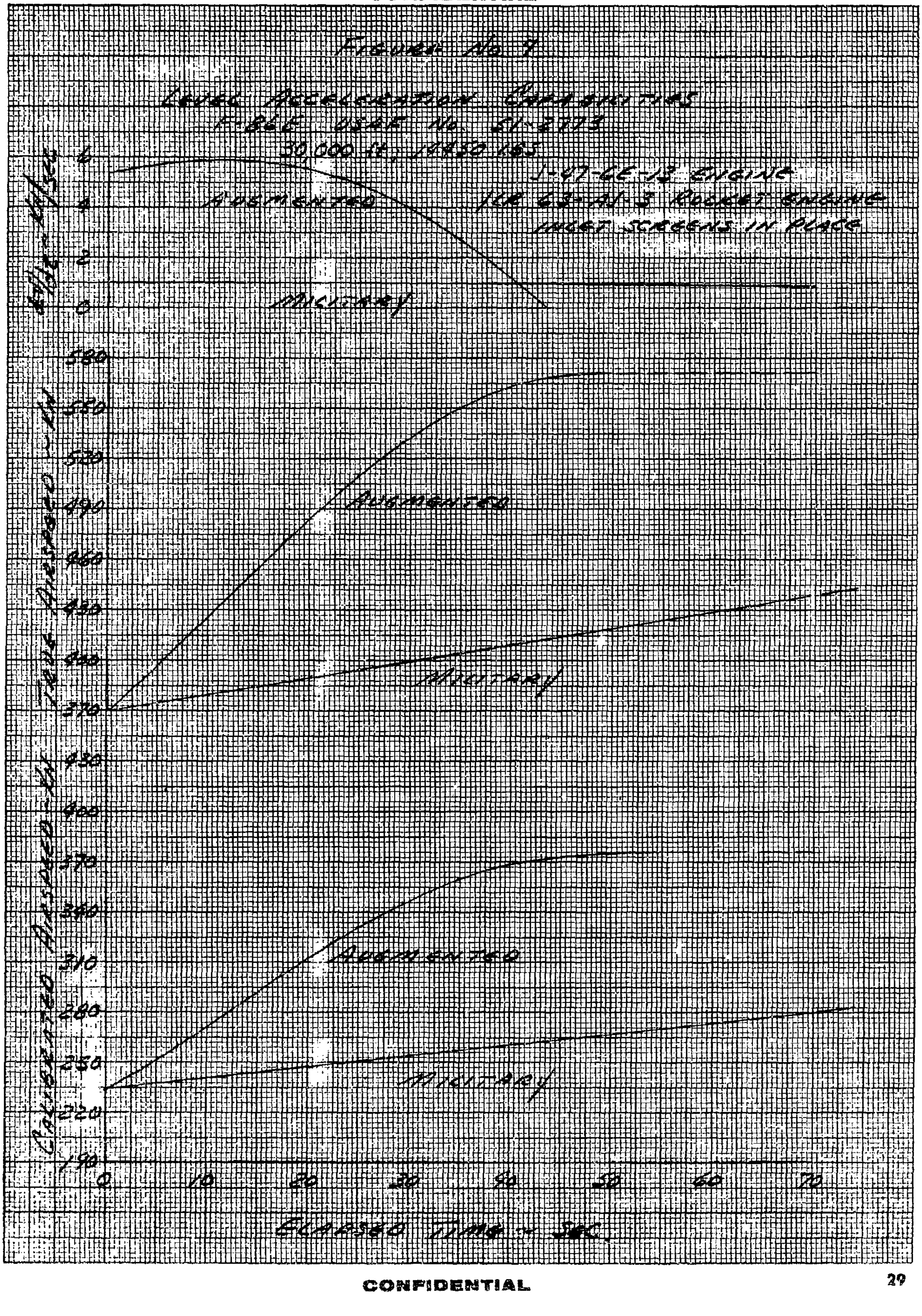


Figure No. 7
Level Acceleration Capabilities
F-86E USAF No. 51-2773
30,000 ft, 14450 lbs
J-47-GE-13 Engine
LR 63-AJ-3 Rocket Engine
Inlet Screens in Place
Augmented
Military
True Airspeed ~ kn
Calibrated Airspeed ~ kn
Augmented
Military
Augmented
Military
Elapsed Time ~ Sec.

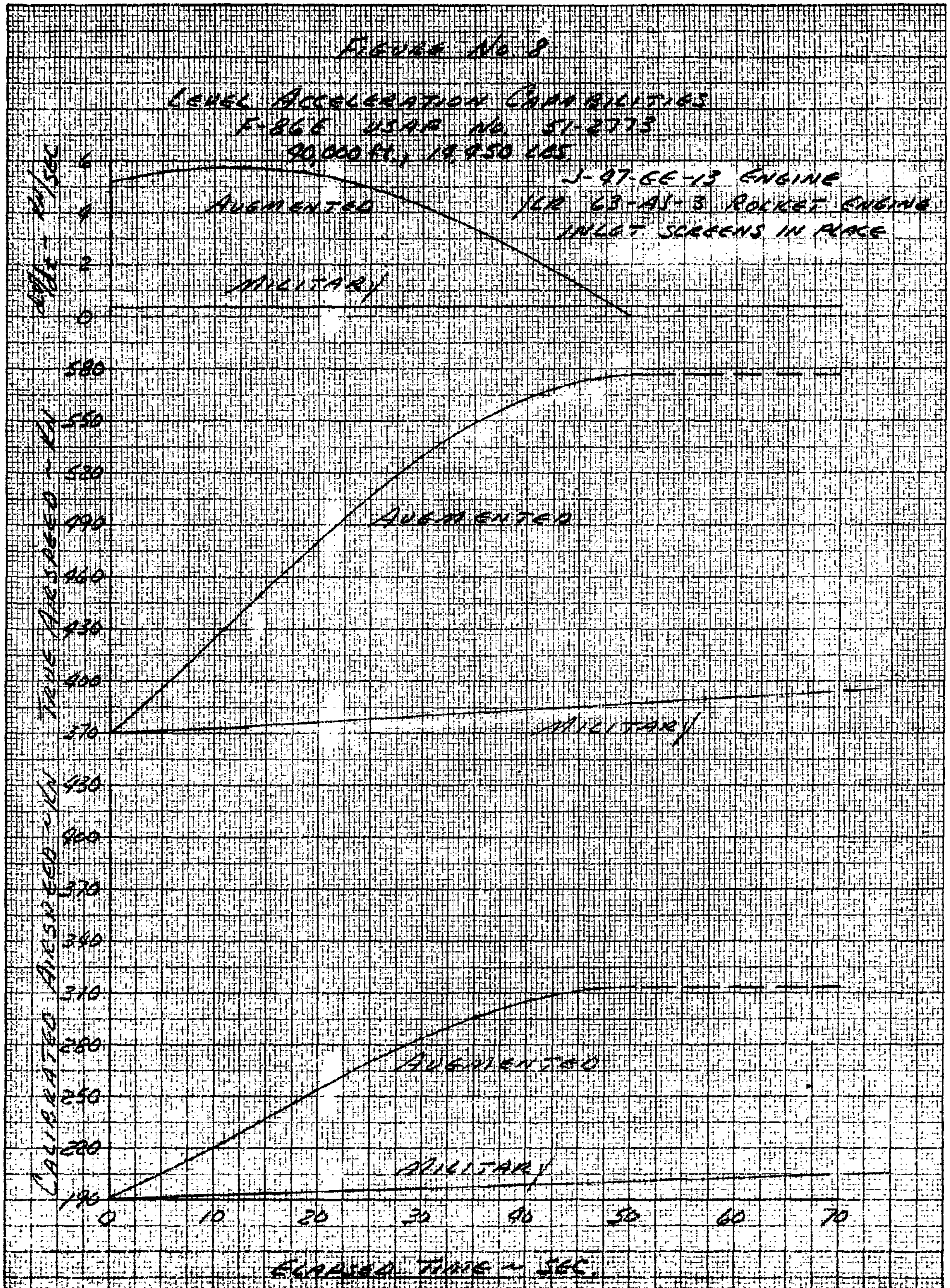


FIGURE No 8
LEVEL ACCELERATION CAPABILITIES
F-86E USAF No. 51-2773
40,000 ft., 19,450 LBS
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
INLET SCREENS IN PLACE
AUGMENTED
MILITARY
AUGMENTED
MILITARY
AUGMENTED
MILITARY
0
10
20
30
40
50
60
70
ELAPSED TIME ~ SEC.

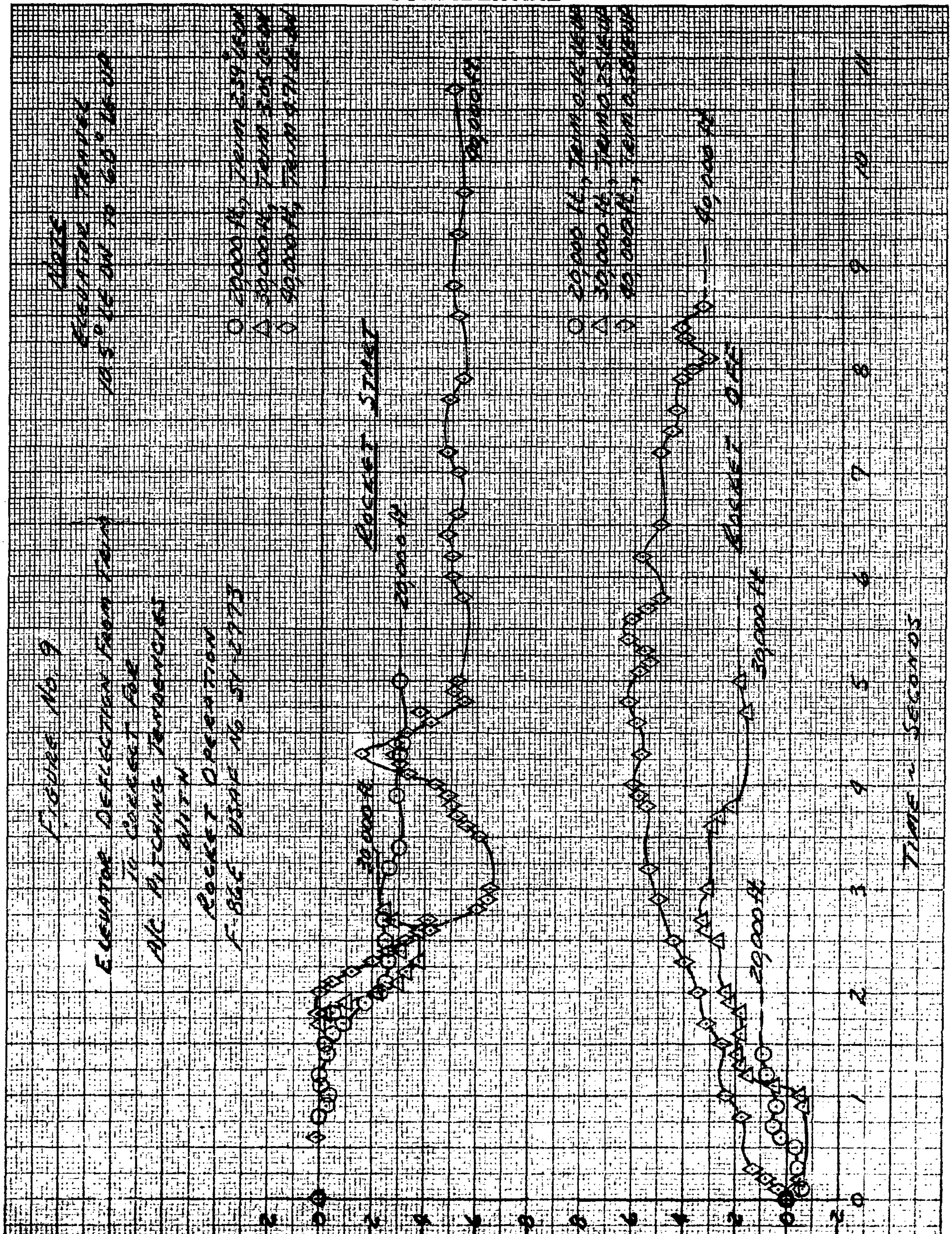


Figure No. 9
Elevator Deflection from Trim
To Correct for
A/C Pitching Tendencies
With
Rocket Operation
Note
Rocket Start
Rocket Off
Time ~ Seconds

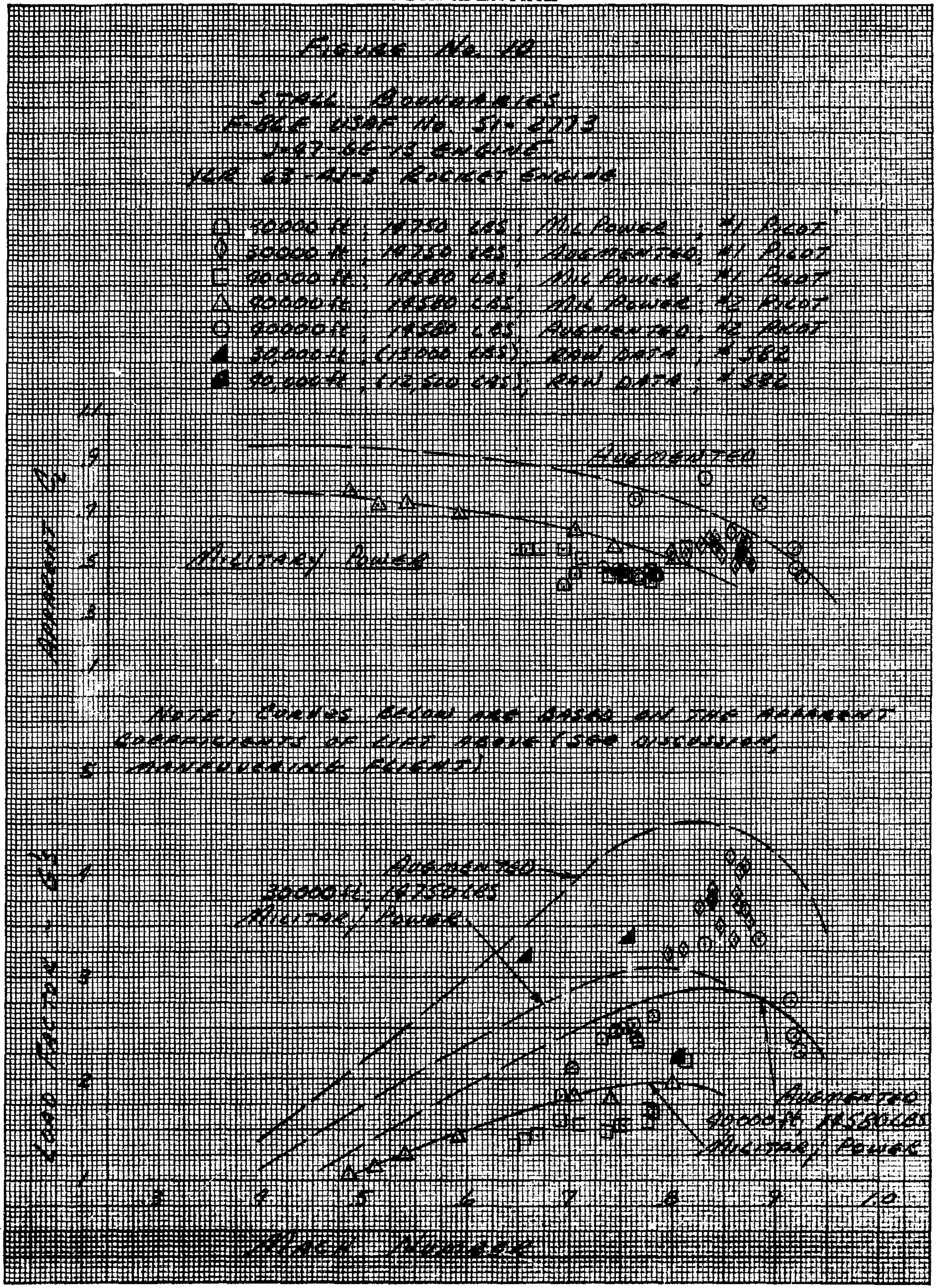
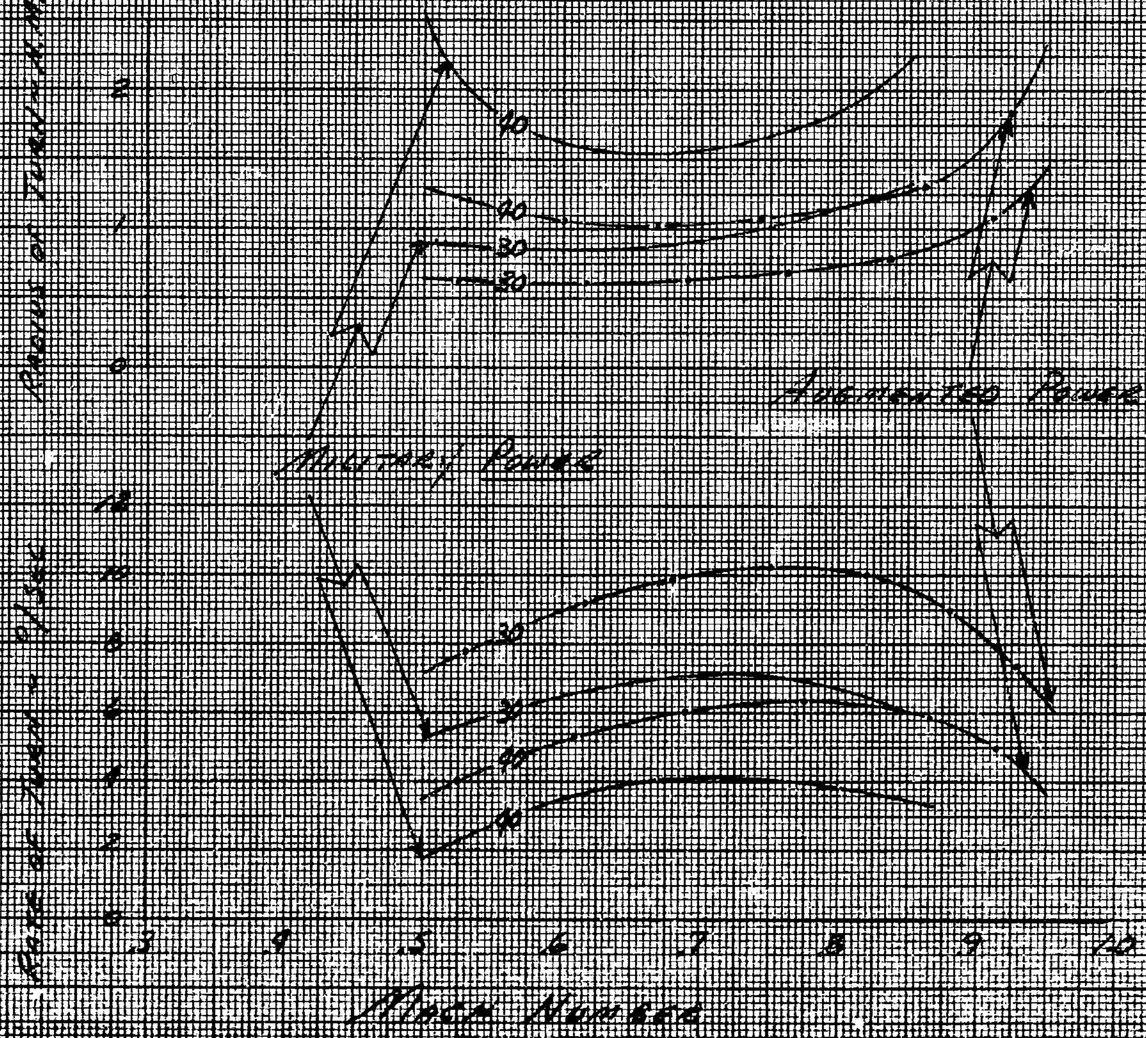


FIGURE No. 10
STALL BOUNDARIES
F-86E USAF No. 51-2773
J47-GE-13 ENGINE
YLR 63-AJ-3 ROCKET ENGINE
30000 ft ; 14750 LBS ; MIL POWER ; #1 PILOT
30000 ft ; 14750 LBS ; AUGMENTED ; #1 PILOT
40000 ft ; 14580 LBS ; MIL POWER ; #1 PILOT
40000 ft ; 14580 LBS ; MIL POWER ; #2 PILOT
40000 ft ; 14580 LBS ; AUGMENTED ; #2 PILOT
30,000 ft ; (13,000 LBS) ; RAW DATA ; #582
40,000 ft ; (12,500 LBS) ; RAW DATA ; #582
APPARENT C_L
AUGMENTED
MILITARY POWER
NOTE: CURVES BELOW ARE BASED ON THE APPARENT COEFFICIENTS OF LIFT ABOVE (SEE DISCUSSION, MANEUVERING FLIGHT)
AUGMENTED
30000 ft. 14750 LBS
MILITARY POWER
AUGMENTED
40000 ft. 14580 LBS
MILITARY POWER
LOAD FACTOR - G's
MACH NUMBER

Figure No. 11

Maneuvering Capabilities
F-86E USAF No. 51-2773
J-47-GE-13 Engine
XLR 63-AJ-5 Rocket Engine

Note
30 ; 30000 ft, 14750 lbs
40 ; 40,000 ft, 14580 lbs



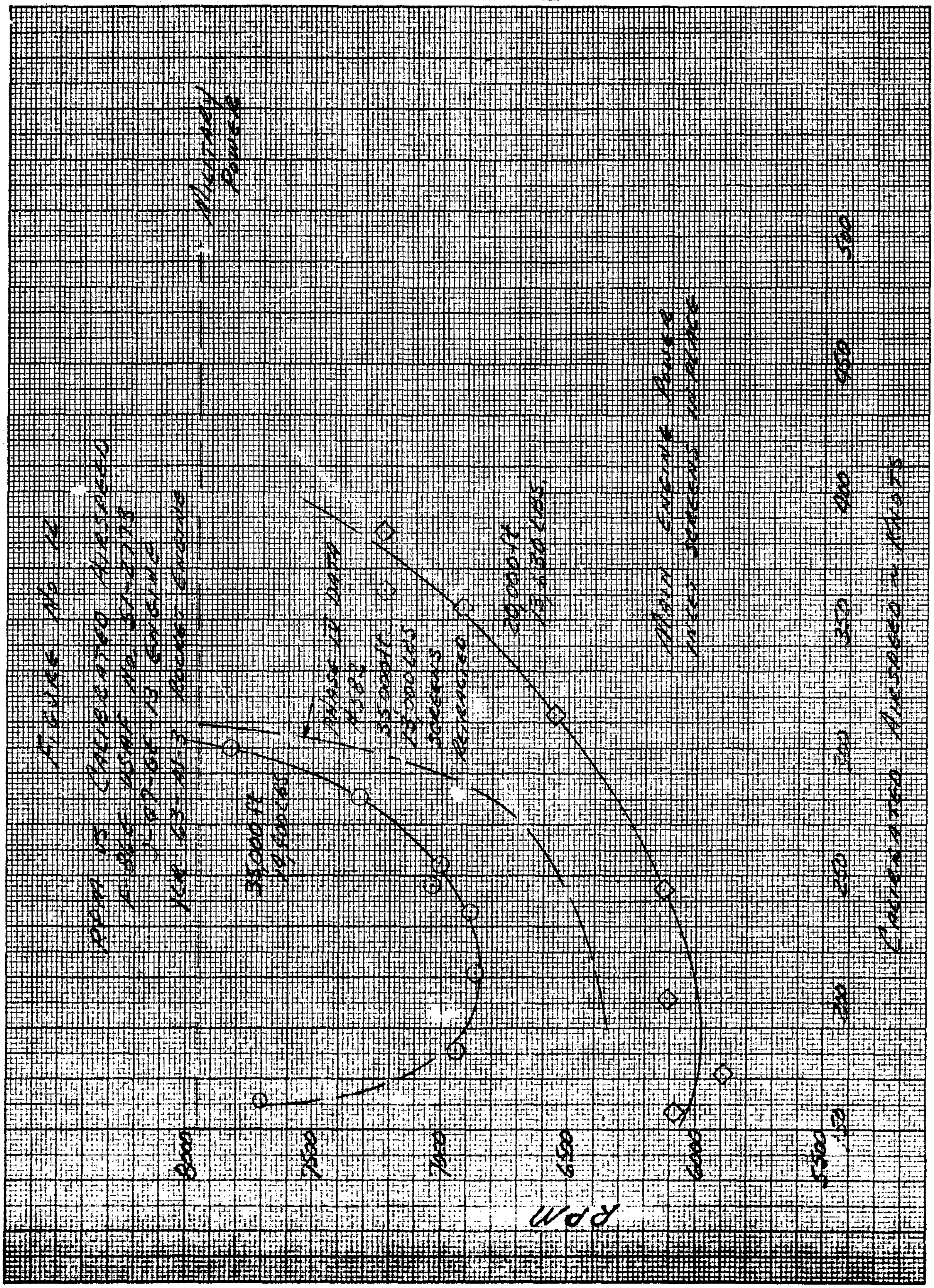


FIGURE NO. 12
RPM VS CALIBRATED AIRSPEED
J-47-GE-13 ENGINE
ROCKET ENGINE
MILITARY POWER
35,000 ft
PHASE II DATA
SCREENS
RETRACTED
20,000 ft
MAIN ENGINE POWER
INLET SCREENS IN PLACE
RPM
8000
7500
7000
6500
6000
5500
150
200
250
300
350
400
450
500
CALIBRATED AIRSPEED ~ KNOTS

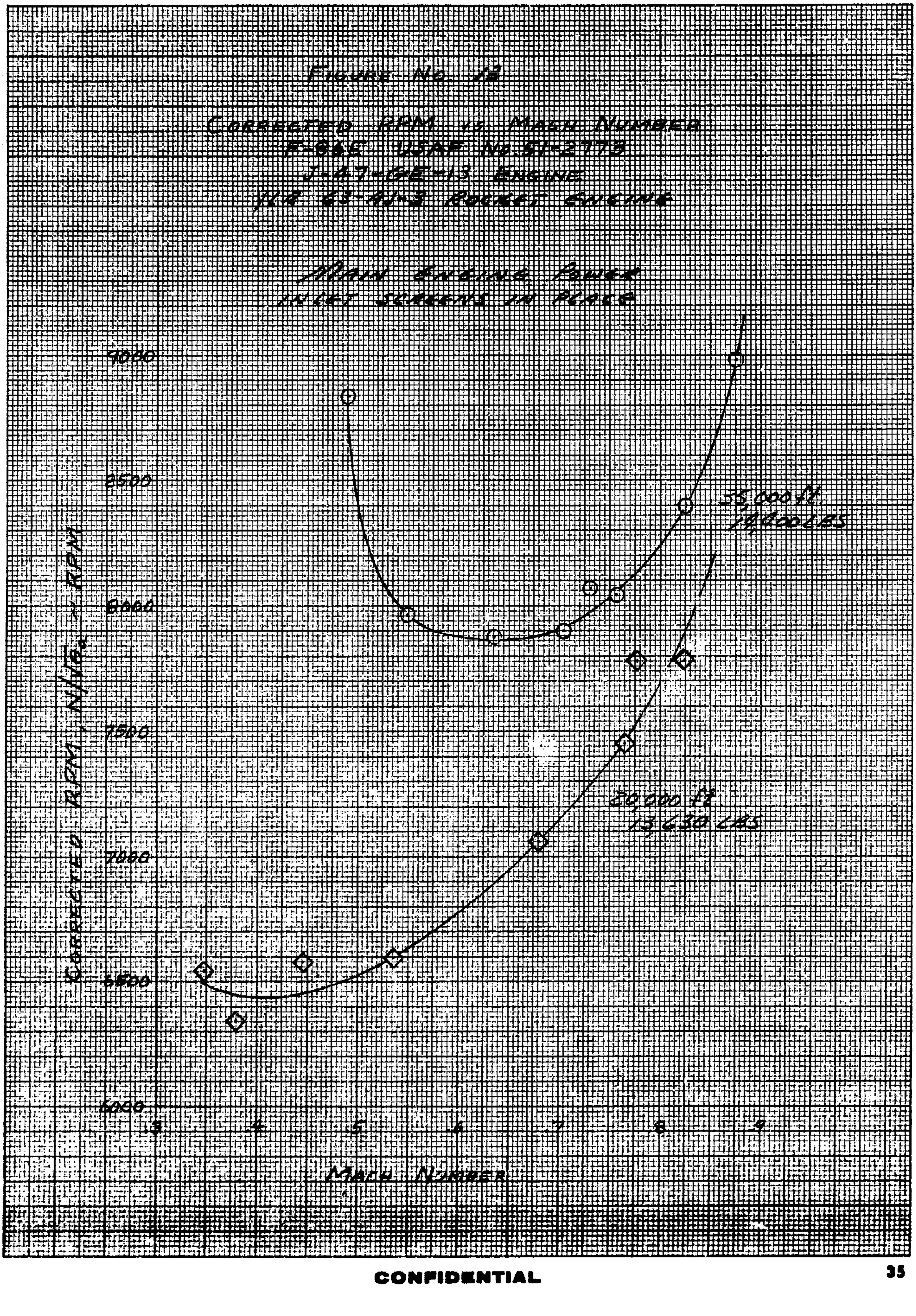
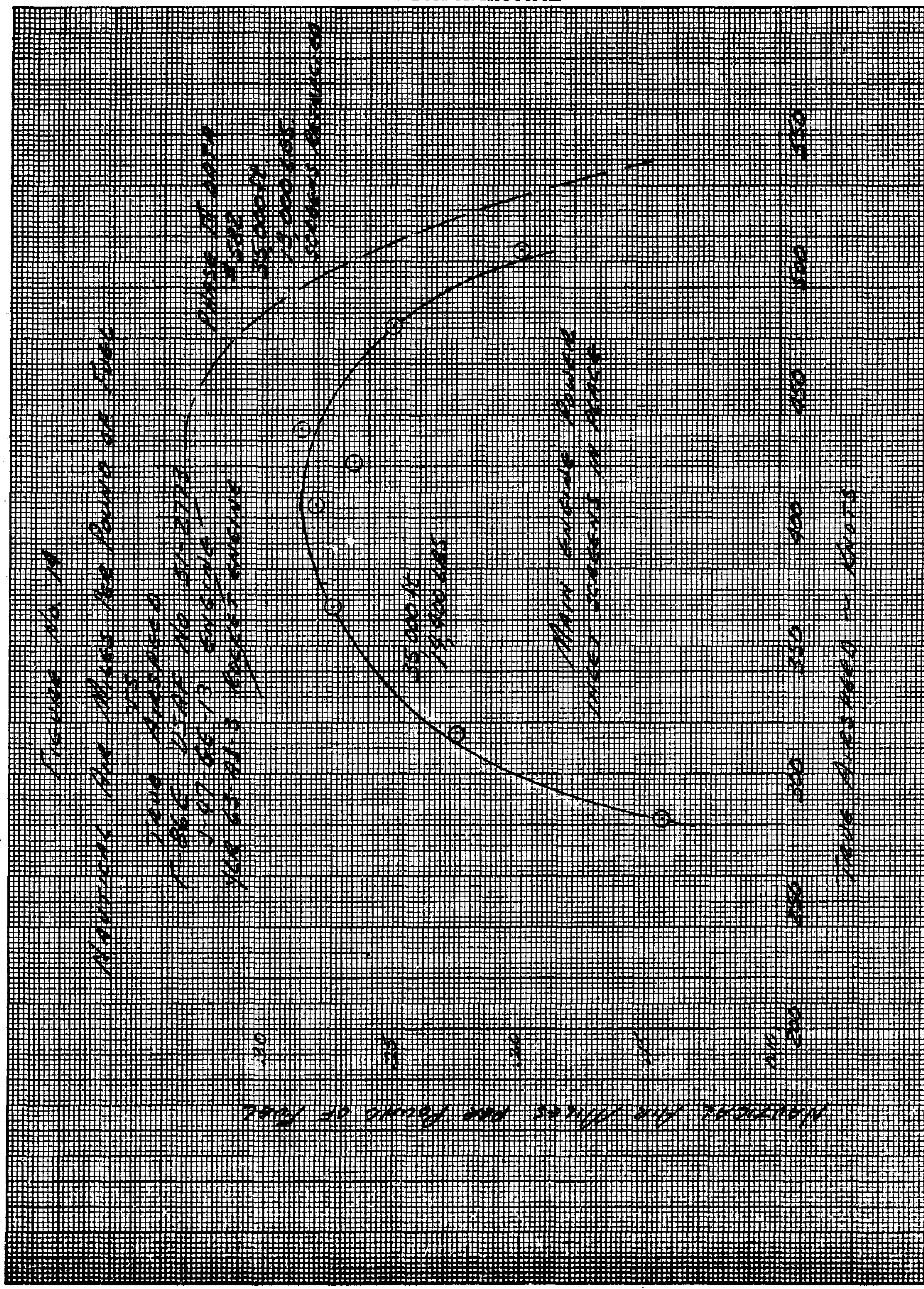


FIGURE NO. 12
CORRECTED RPM vs MACH NUMBER
F-86E USAF No. 51-2773
J-47-GE-13 ENGINE
XLR 63-AJ-3 ROCKET ENGINE
MAIN ENGINE POWER
INLET SCREENS IN PLACE
9000
8500
8000
7500
7000
6500
6000
.3
.4
.5
.6
.7
.8
.9
35,000 ft.
14,400 LBS
20,000 ft
13,630 LBS
CORRECTED RPM, $N/\sqrt{\theta_a}$ ~ RPM
MACH NUMBER



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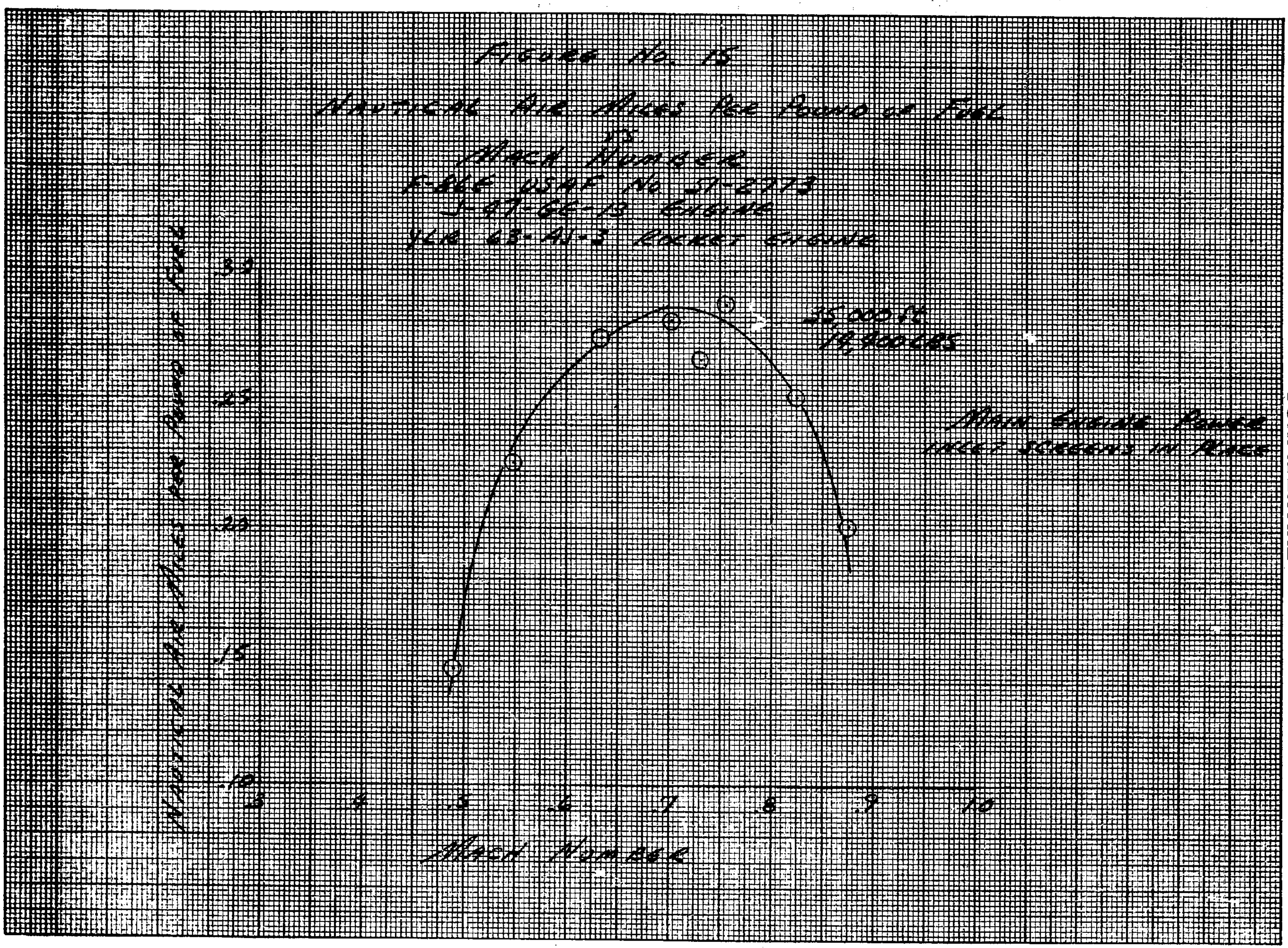


Figure No. 15
Nautical Air Miles Per Pound of Fuel
vs
Mach Number
F-86E USAF No 51-2773
J-47-GE-13 Engine
XLR 63-AJ-3 Rocket Engine
35,000 ft
14,400 LBS
Main Engine Power
Inlet Screens in Place
Nautical Air Miles Per Pound of Fuel
.30
.25
.20
.15
.10
.3
.4
.5
.6
.7
.8
.9
1.0
Mach Number

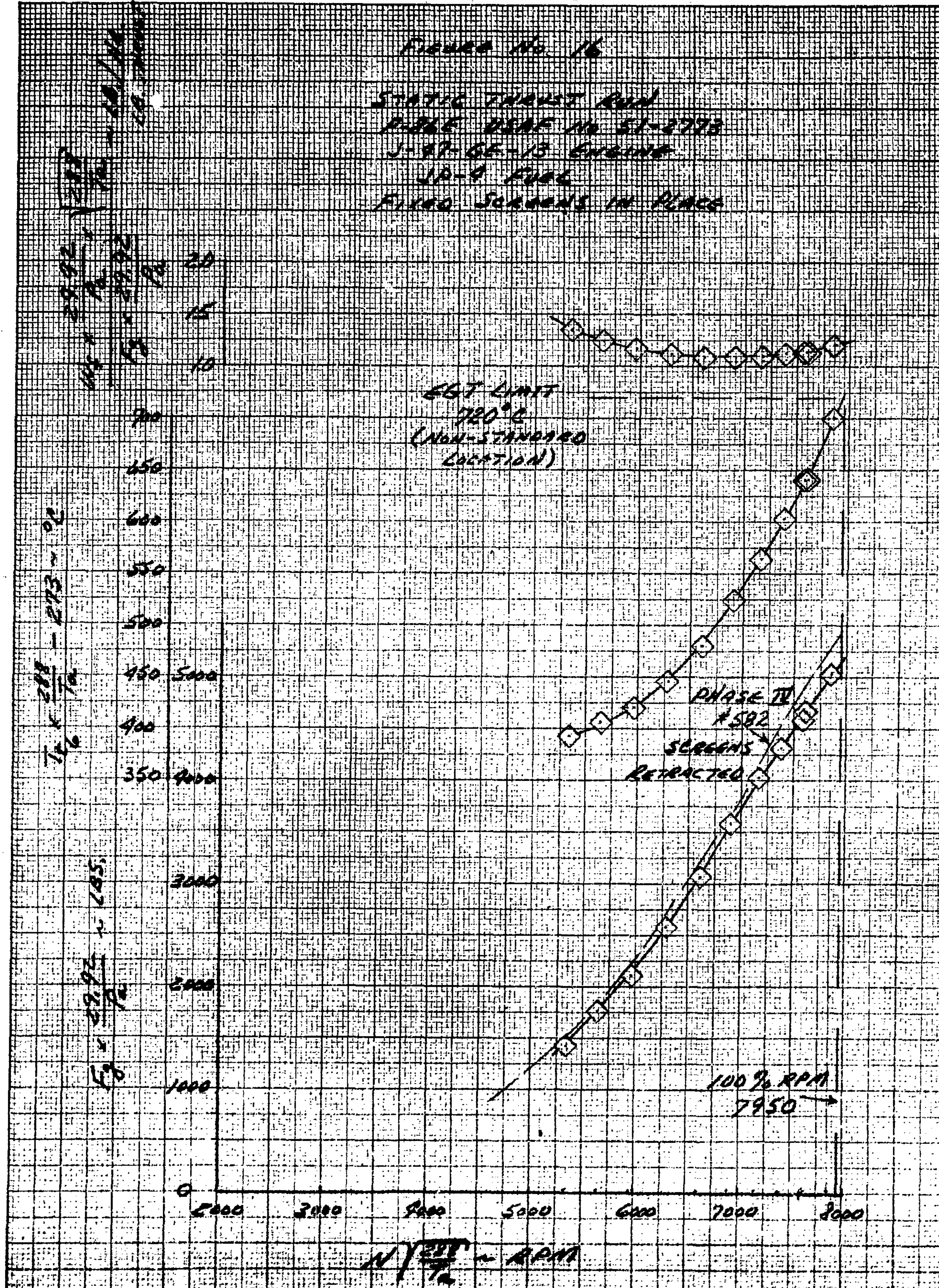


FIGURE No. 16
STATIC THRUST RUN
F-86F USAF No 51-2793
J-47-GE-13 ENGINE
JP-4 FUEL
FIXED SCREENS IN PLACE
EGT LIMIT
720°C
(NON-STANDARD
LOCATION)
PHASE IV
#582
SCREENS
RETRACTED
100% RPM
7950
2000
3000
4000
5000
6000
7000
8000

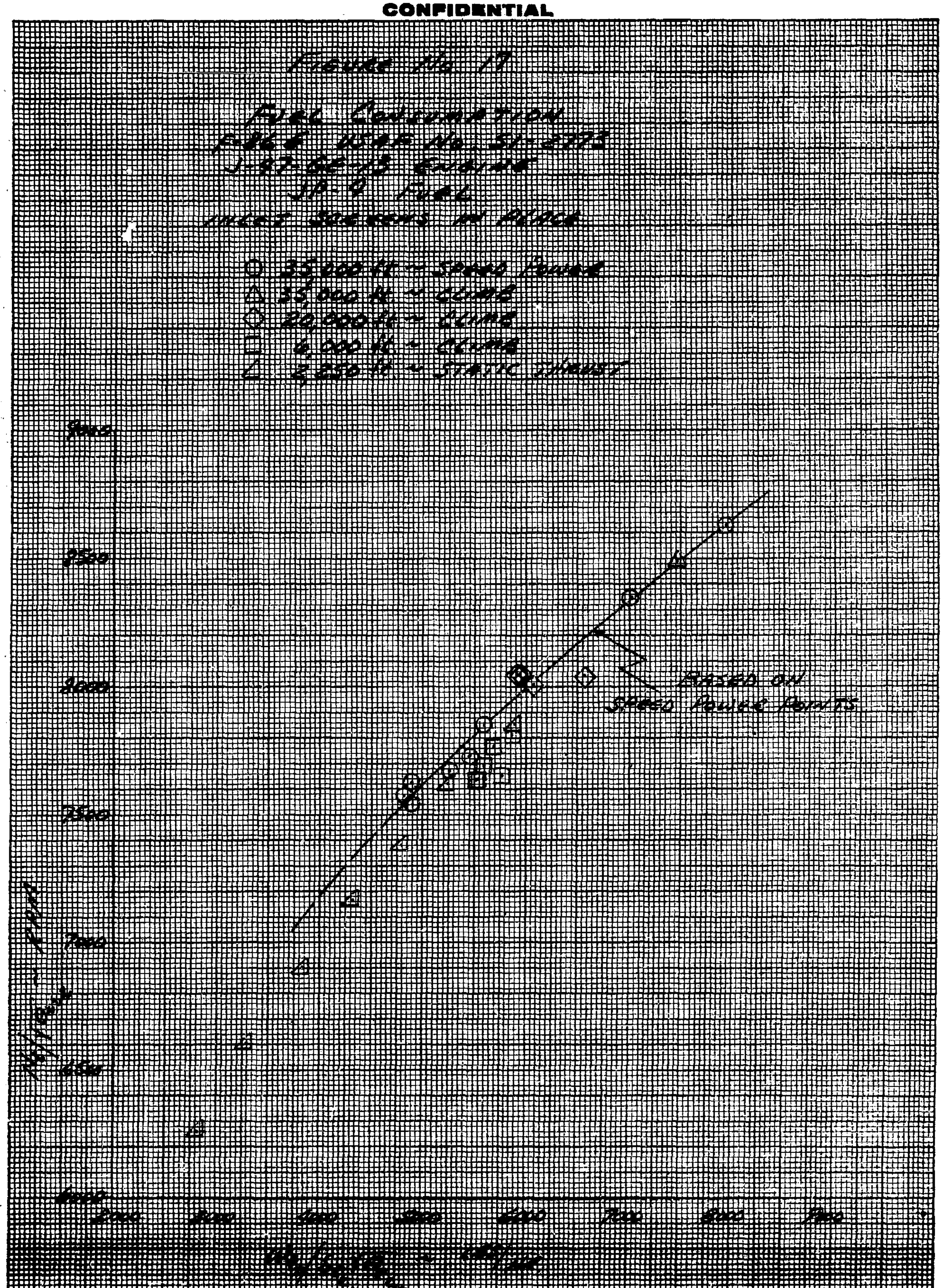


FIGURE NO. 17
FUEL CONSUMPTION
JP-4 FUEL
INLET SCREENS IN PLACE
35,000 ft ~ SPEED POWER
35,000 ft ~ CLIMB
20,000 ft ~ CLIMB
6,000 ft ~ CLIMB
2,250 ft ~ STATIC THRUST
BASED ON
SPEED POWER POINTS

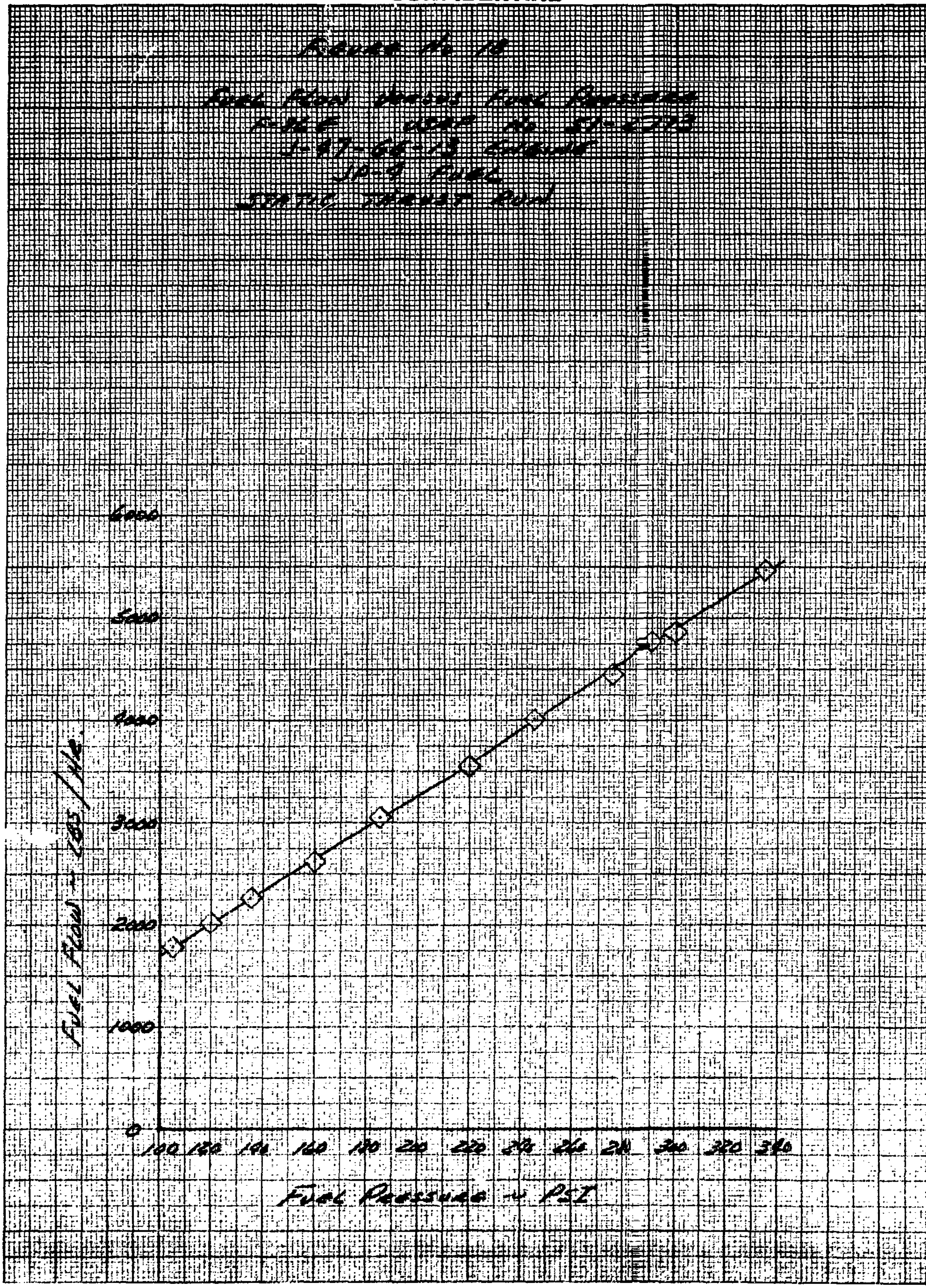


Figure No 18
Fuel Flow Versus Fuel Pressure
JP-4 Fuel
Static Thrust Run
Fuel Flow ~ LBS/HR
6000
5000
4000
3000
2000
1000
0
100
120
140
160
180
200
220
240
260
280
300
320
340
Fuel Pressure ~ PSI

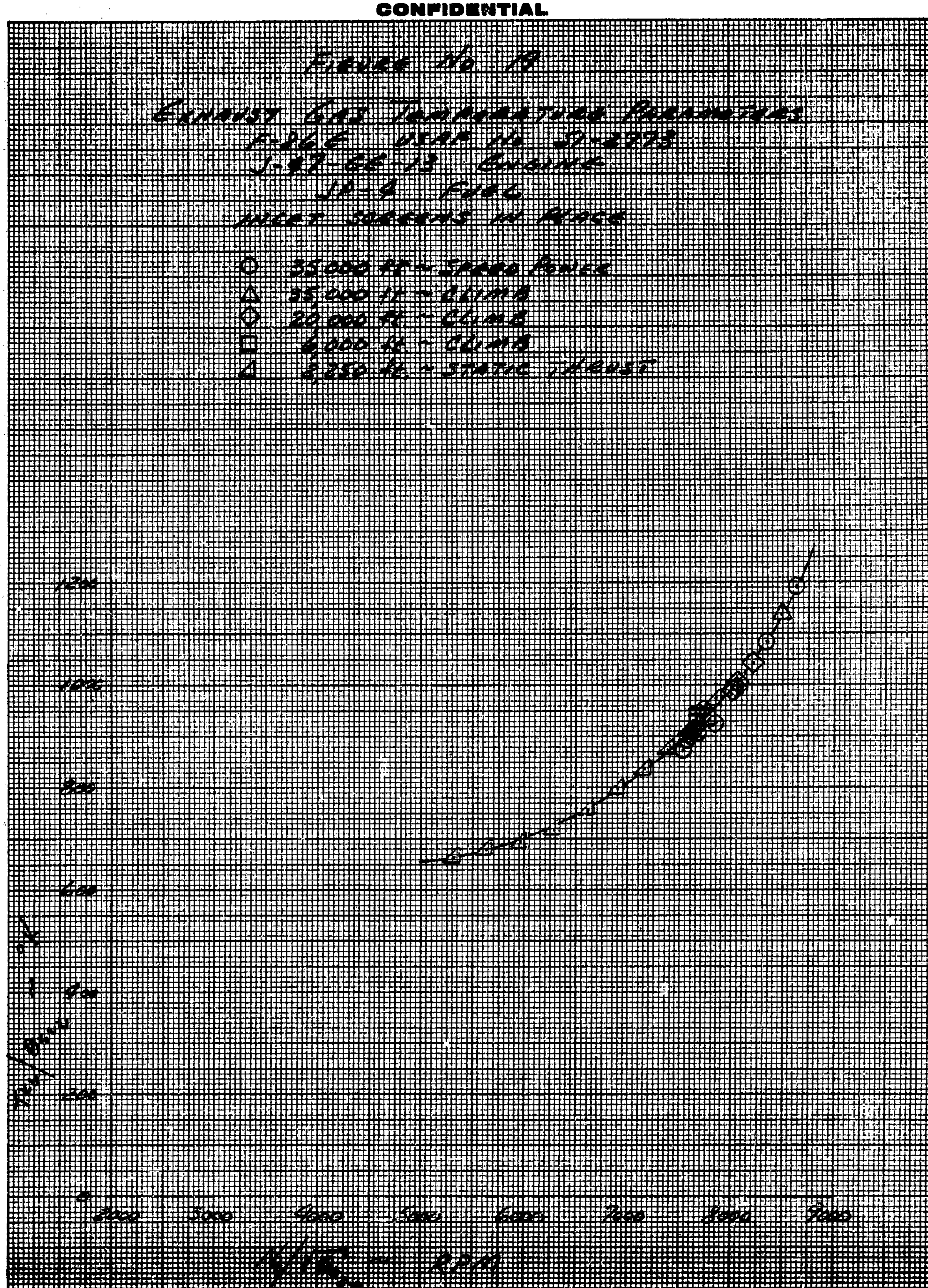


FIGURE No. 19
EXHAUST GAS TEMPERATURE PARAMETERS
F-86E USAF No. 51-2773
J-47-GE-13 ENGINE
JP-4 FUEL
INLET SCREENS IN PLACE
○ 35000 ft ~ SPEED POWER
△ 35000 ft ~ CLIMB
◇ 20000 ft ~ CLIMB
□ 6000 ft ~ CLIMB
◿ 2,250 ft ~ STATIC THRUST
1200
1000
800
600
400
200
0
2000
3000
4000
5000
6000
7000
8000
9000
~ RPM

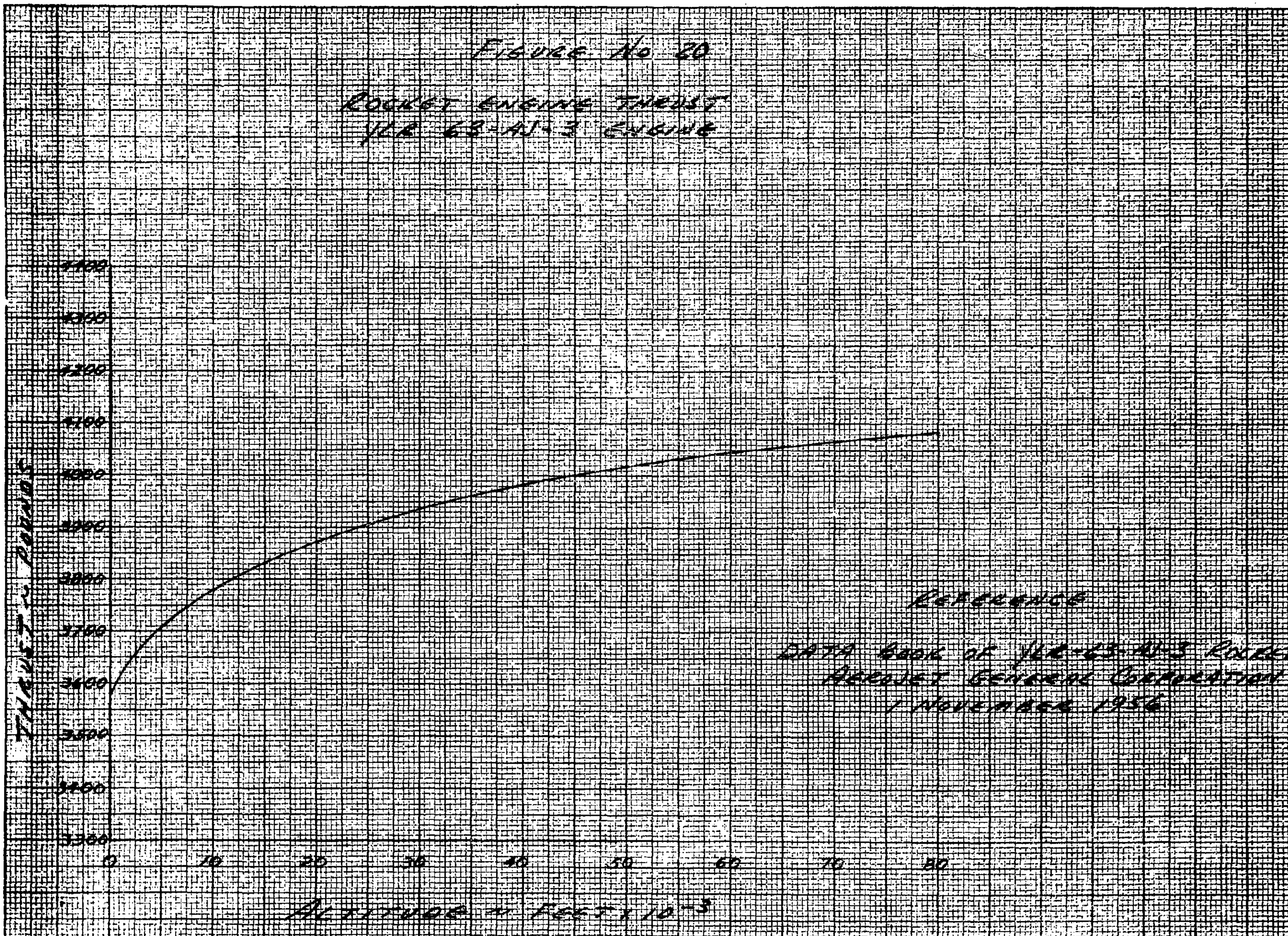


FIGURE No 20
ROCKET ENGINE THRUST
YLR 63-AJ-3 ENGINE
THRUST ~ POUNDS
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
0
10
20
30
40
50
60
70
80
ALTITUDE ~ FEET x 10^-3
REFERENCE
DATA BOOK OF YLR-63-AJ-3 ROCKET
AEROJET GENERAL CORPORATION
1 NOVEMBER 1956

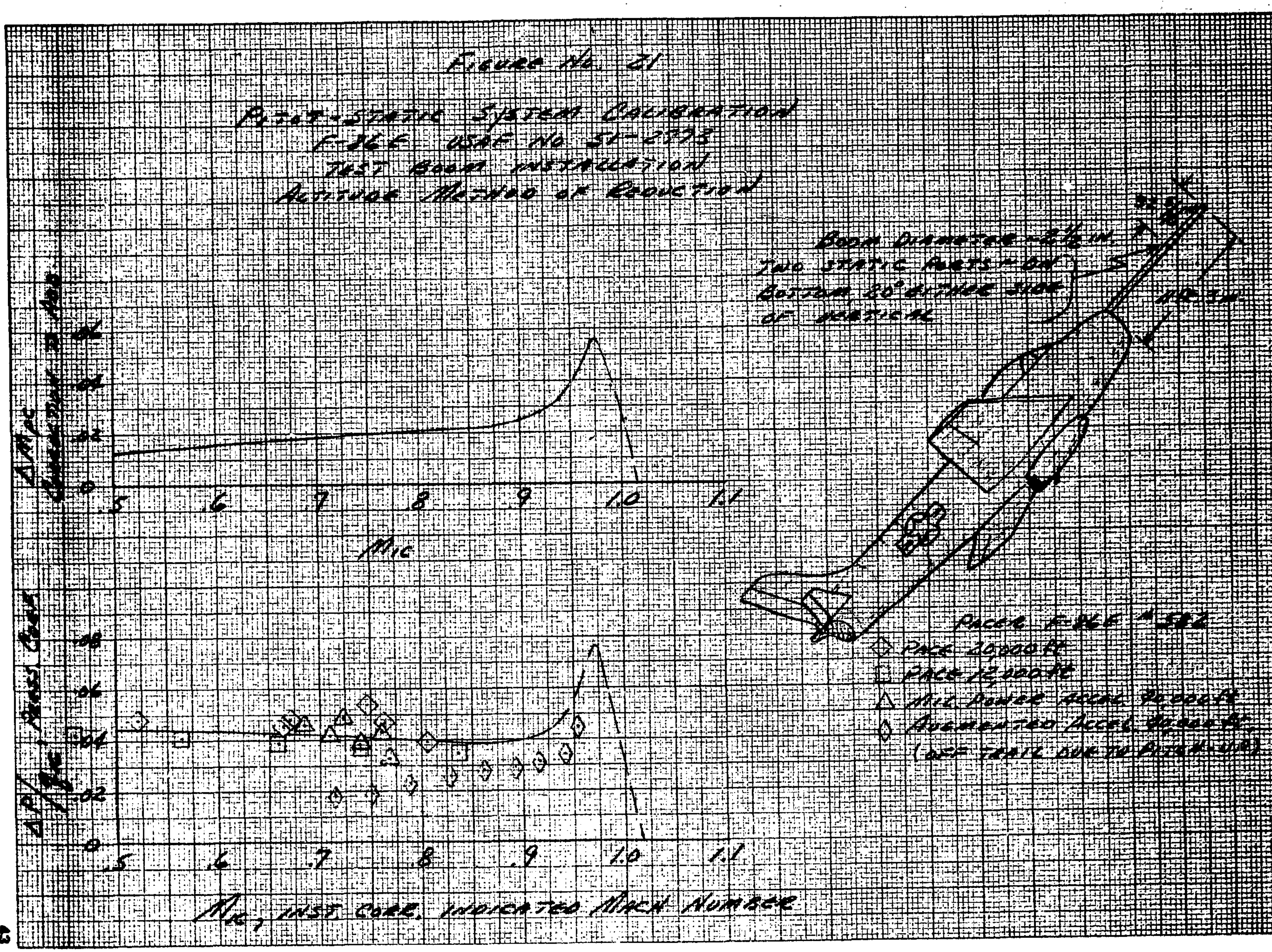
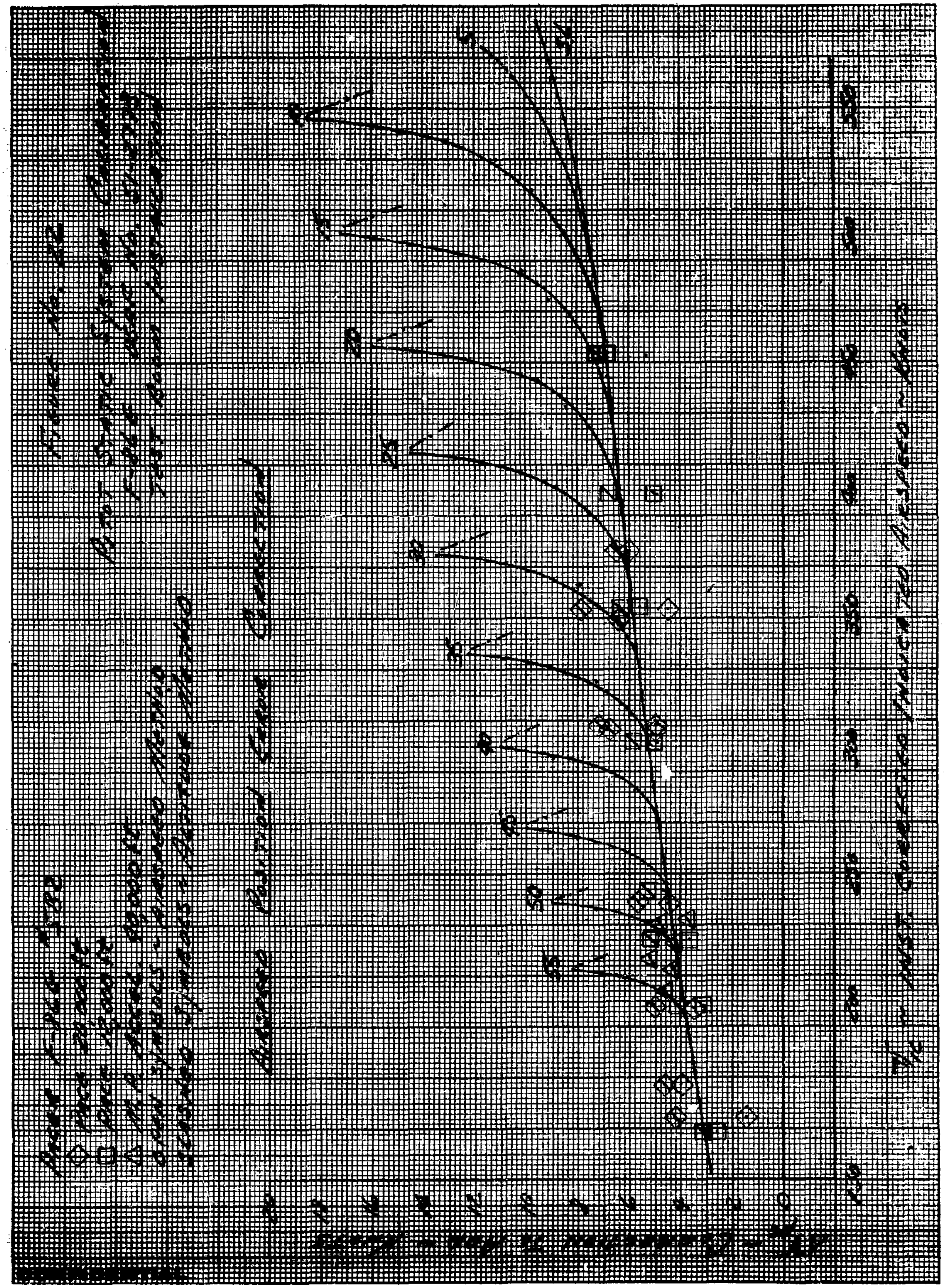


Figure No. 21
Pitot-Static System Calibration
F-86F USAF No 51-2773
Test Boom Installation
Altitude Method of Reduction
Boom Diameter = 2 1/2 in.
Two Static Ports - On Bottom 80° Either Side of Vertical
Pacer F-86F #582
Pace 20000 Ft
Pace 12000 Ft
Mil Power Accel 30000 Ft
Augmented Accel 30000 Ft
(Off Trail Due to Pitch-Up)
ΔM_{pc}
M_{ic}
$\Delta P/P_{sc}$
.5
.6
.7
.8
.9
1.0
1.1
0
.02
.04
.06
.08
M_{ic}, Inst. Corr. Indicated Mach Number



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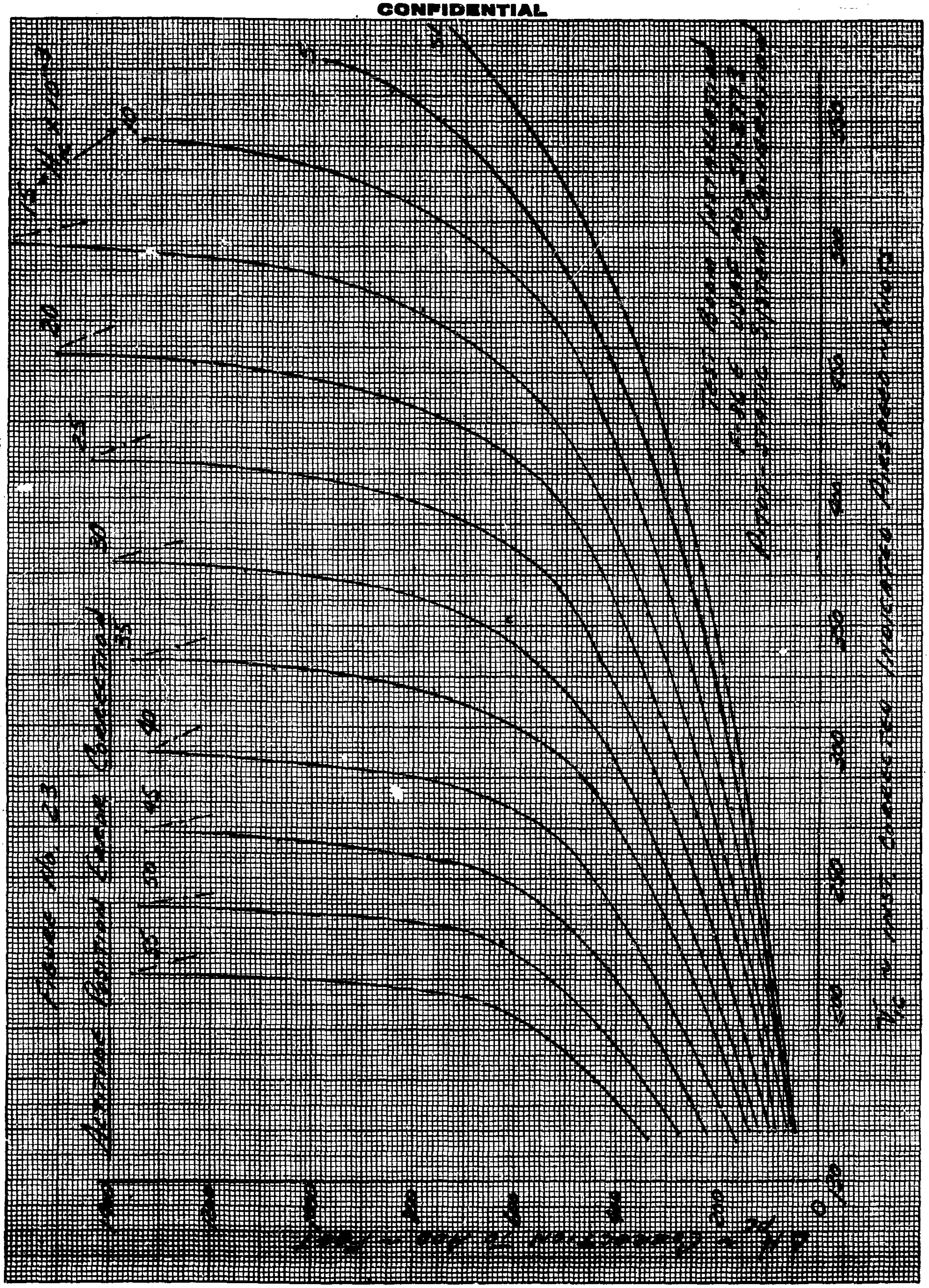
Figure No. 23
Altitude Position Error Correction
Test Boom Instrumented
Pitot-Static System Calibration
V_c ~ Inst. Corrected Indicated Airspeed ~ Knots
0
150
200
250
300
350
400
450
500
550
5
10
15
20
25
30
35
40
45
50
55

APPENDIX III

general aircraft information

aircraft dimensions

General Dimensions:

Span	37.12 ft.
Length (overall)	37.54 ft.
Height (to tip of fin)	17.74 ft.
Wing:	
Area (including fuselage, flaps and ailerons)	302.26 ft.^{2}
MAC	97.03 in.
Aspect ratio	4.785
Airfoil section	
root	NACA-0012-64
tip	NACA-0011-64
Incidence (in buttock plane)	
root	+1°
tip	−1°
Thickness (percent chord)	
root	10.09
tip	8.93
Sweepback (25 percent chord line)	35° 13′ 31.4″
Dihedral	3°

flight limitations

Maximum weight	17,700 lbs.
Allowable cg range	19.5 to 25.5% MAC
Airspeed Limitations	
Clean	600 kts.
Gear and flaps	185 kts.
Mach limitations	Excessive wing roll
Normal acceleration	
Clean	+6.0*
	+3.3 rolling
	−3.0**
Tanks	+5.0
	−2.00**

*Limit with rocket engine installed.

**No sustained negative accelerations allowed with rocket operating.

power plant

Main Engine	J47-GE-13 turbo jet
Augmentation	YLR63-AJ-3 rocket

weight and balance

Basic Weight	12,442	12,442	12,442	12,442
Pilot	230	230	230	230
Oil (3.4 gallon)	26	26	26	26
Internal fuel (330 gallon)	2,146	2,146	2,146	2,146
External fuel (120 gallon)	—	780	—	780
Oxidizer (85 gallon)	—	—	1,063	1,063
Other rocket fluids (or H_2O)	80	80	80	80
Weight, Engine Start*	14,924	15,804**	15,987	16,867**
CG, percent MAC	20.3	20.9	23.1	23.4

*Based on a fuel density of 6.5 pounds per gallon.

**Including 100 pound 120-gallon tank which was dropped prior to tests.

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE OHIO

FEB 19 2002

MEMORANDUM FOR DTIC/OCQ (ZENA ROGERS)
8725 JOHN J. KINGMAN ROAD, SUITE 0944
FORT BELVOIR VA 22060-6218

FROM: AFMC CSO/SCOC
4225 Logistics Avenue, Room S132
Wright-Patterson AFB OH 45433-5714

SUBJECT: Technical Reports Cleared for Public Release

References: (a) HQ AFMC/PAX Memo, 26 Nov 01, Security and Policy Review, AFMC 01-242 (Atch 1)

(b) HQ AFMC/PAX Memo, 19 Dec 01, Security and Policy Review, AFMC 01-275 (Atch 2)

(c) HQ AFMC/PAX Memo, 17 Jan 02, Security and Policy Review, AFMC 02-005 (Atch 3)

1. Technical reports submitted in the attached references listed above are cleared for public release in accordance with AFI 35-101, 26 Jul 01, *Public Affairs Policies and Procedures*, Chapter 15 (Cases AFMC 01-242, AFMC 01-275, & AFMC 02-005).

2. Please direct further questions to Lezora U. Nobles, AFMC CSO/SCOC, DSN 787-8583.

Lezora U. Nobles

LEZORA U. NOBLES
AFMC STINFO Assistant
Directorate of Communications and Information

Attachments:
1. HQ AFMC/PAX Memo, 26 Nov 01
2. HQ AFMC/PAX Memo, 19 Dec 01
3. HQ AFMC/PAX Memo, 17 Jan 02

cc:
HQ AFMC/HO (Dr. William Elliott)

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE OHIO

JAN 17 2002

MEMORANDUM FOR HQ AFMC/HO

FROM: HQ AFMC/PAX

SUBJECT: Security and Policy Review, AFMC 02-005

1. The reports listed in your attached letter were submitted for security and policy review IAW AFI 35-101, Chapter 15. They have been cleared for public release.

2. If you have any questions, please call me at 77828. Thanks.

James A. Morrow

JAMES A. MORROW
Security and Policy Review
Office of Public Affairs

Attachment:
Your Ltr 14 January 2002

14 January 2002

MEMORANDUM FOR: HQ AFMC/PAX
Attn: Jim Morrow

FROM: HQ AFMC/HO

SUBJECT: Releasability Reviews

1. Please conduct public releasability reviews for the following attached Defense Technical Information Center (DTIC) reports:

   a. *Flight Test Program for Model P-86 Airplane Class – Jet Propelled Fighter*, 2 December 1946; DTIC No. AD-B804 069.

   b. *Physiological Recognition of Strain in Flying Personnel: Eosinopenia in F-86 Combat Operations*, September 1953; DTIC No. AD- 020 375.

   c. *Phase IV Performance Test of the F-86F-40 Airplane Equipped with 6x3-inch Leading Edge Slats and 12-inch Extensions on the Wing Tips*, May 1956; DTIC No. AD- 096 084.

   d. *F-86E Thrust Augmentation Evaluation*, March 1957; DTIC No. AD- 118 703.

   e. *F-86E Thrust Augmentation Evaluation*, Appendix IV, March 1957; DTIC No. AD- 118 707.

   f. *A Means of Comparing Fighter Effectiveness in the Approach Phase*, October 1949; DTIC No. AD- 223 596.

   g. *War Emergency Thrust Augmentation for the J47 Engine in the F-86 Aircraft*, August 1955; DTIC No. AD- 095 757.

   h. *Operational Suitability Test of the F-86F Airplane*, 4 May 1953; DTIC No. AD- 017 568.

   i. *Estimated Aerodynamic Characteristics for Design of the F-86E Airplane*, 26 December 1950; DTIC No. AD- 069 271.

   j. *Combat Suitability Test of F-86F-2 Aircraft with T-160 Guns*, August 1953; DTIC No. AD- 019 725.

2. These attachments have been requested by Dr. Kenneth P. Werrell, a private researcher.

3. The AFMC/HO point of contact for these reviews is Dr. William Elliott, who may be reached at extension 77476.

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10 Attachments:
a. DTIC No. AD-B804 069
b. DTIC No. AD- 020 375
c. DTIC No. AD- 096 084
d. DTIC No. AD- 118 703
e. DTIC No. AD- 118 707
f. DTIC No. AD- 223 596
g. DTIC No. AD- 095 757
h. DTIC No. AD- 017 568
i. DTIC No. AD- 069 271
j. DTIC No. AD- 019 725